Title

Distinct associations of different sedentary behaviors with health-related attributes among older adults

Authors

Hiroyuki Kikuchi Ph.D.[1] , Shigeru Inoue, M.D., Ph.D. [1], Takemi Sugiyama, Ph.D. [2], Neville Owen, Ph.D. [3,6-8], Koichiro Oka, Ph.D. [4] , Tomoki Nakaya Ph.D. [5] and Teruichi Shimomitsu, M.D., Ph.D. [1, 9]

Authors' Affiliations and Addresses

1. Department of Preventive Medicine and Public Health, Tokyo Medical University,
   6-1-1 Shinjuku Shinjuku-ku Tokyo 160-8402 Japan

2. Sansom Institute for Health Research & School of Population Health, University of South Australia
   North Terrace, Adelaide SA 5000, Australia

3. Behavioural Epidemiology Laboratory, Baker IDI Heart and Diabetes Institute
   Level 4, 99 Commercial Rd, Melbourne, Victoria, 3004, Australia

4. Faculty of Sport Sciences, Waseda University
   2-579-15 Mikajima, Tokorozawa, Saitama, 359-1192, Japan

5. Department of Geography and Institute of Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University
   58 Komatsubara Kitamachi, Kita-ku, Kyoto, Kyoto 603-8341, Japan

6. School of Population Health, The University of Queensland
   Level 2, Public Health Building,School of Population Health, University of Queensland, Herston Road Herston QLD, Brisbane, 4006, Australia

7. Melbourne School of Population Health, the University of Melbourne
   Level 5, 207 Bouverie Street,The University of Melbourne, Victoria 3010 Australia"

8. School of Medicine, Monash University.
Faculty of Medicine, Nursing and Health Sciences, Monash University, Victoria 3800, Australia

9. Japan Health Promotion and Fitness Foundation
2-6-10 Dai-Tokyo-Building7F, Highashi-Shinbashi, Minato-ku, Tokyo, 105-0021, Japan

Email addresses
HK: kikuchih@tokyo-med.ac.jp
SI: inoue@tokyo-med.ac.jp
TSU: takemi.sugiyama@unisa.edu.au
NO: neville.owen@bakeridi.edu.au
KO: koka@waseda.jp
TN: nakaya@lt.ritsumei.ac.jp
TSI: tshimo@tokyo-med.ac.jp

Corresponding author: Hiroyuki Kikuchi
Tokyo Medical University
6-1-1 Shinjuku Shinjuku-ku Tokyo 160-8402 Japan
Email: kikuchih@tokyo-med.ac.jp
TEL. +81-3-3351-6141, FAX.+81-3-3353-0162

Word count: 2,724 words for main text, 199 words for abstract

Abstract

Objective

Leisure-time sedentary behaviors (LTSBs) have been associated adversely with health outcomes. However, limited research has focused on different categories of LTSB. We aimed at identifying categories of LTSBs and examining their separate associations with indices of health among Japanese older adults.

Methods

A postal survey collected data on self-reported health, psychological distress, body mass index, moderate-to-vigorous physical activity (MVPA), LTSBs (five behaviors) and socio-demographic characteristics from 1,580 Japanese older adults (67% response rate; 65-74 years) in 2010. Exploratory factor analysis was used to classify LTSBs. Odds ratios (ORs) were calculated for associations of LTSB categories with self-reported health, psychological distress, overweight, and lower MVPA. Data were analyzed in 2013.

Results

Two categories of LTSB: passive sedentary time (consisting of TV time, listening or talking while sitting, and sitting around) and mentally-active sedentary time (consisting of computer-use and reading books or newspapers) were identified. Higher passive sedentary time was associated with a higher odds of being overweight (OR: 1.39, [95%CI: 1.08-1.80]), and lower MVPA (1.26, [1.02-1.54]). Higher mentally-active sedentary time was associated with lower odds of lower MVPA (0.70, [0.57-0.86]).

Conclusions

Two types of sedentary time – passive and mentally-active – may play different roles in older adults' well-being.

Introduction

Sedentary behaviors, which are distinct from lack of moderate-to-vigorous physical activity (MVPA), are associated with increased cardio-metabolic risk (Owen et al., 2010). Studies have shown relationships between higher sitting time and indices of poorer health in general adult samples (Hamilton et al., 2007). Furthermore this relationship has been observed among older adult samples (Gardiner et al., 2011; Inoue et al., 2012). Decreasing sedentary behavior, in addition to increasing physical activity, is now considered an important strategy to reduce health risk (Hamilton et al., 2008; Owen et al., 2011).

In assessing sedentary behaviors, many studies have used measures of television viewing (TV) and other screen time. TV viewing is a predominant sedentary behavior during leisure time (Sugiyama et al., 2008) and higher TV time has been consistently associated with cardiovascular disease (CVD) (Jakes et al., 2003), atherosclerosis (Kronenberg et al., 2000), the metabolic syndrome (Chang et al., 2008; Dunstan et al., 2005), and poor mental health (Hamer et al., 2010). Screen time can include watching TV, computer use, or video game playing. Higher screen time also shows significant associations with all-cause mortality (Ford, 2012), CVD events (Stamatakis et al., 2011; Warren et al., 2010), and obesity (Vandelanotte et al., 2009).

However, recent studies found that specific sedentary behaviors can be differently associated with MVPA and with indices of poorer health. A systematic review has shown that the associations of MVPA with sedentary time differ between TV viewing and computer use (Rhodes et al., 2012). In a study of 3,305 Singaporean adults, higher risk of cardio-metabolic diseases was associated with higher TV time, but not with computer-use and reading time (Nang et al., 2013). In a longitudinal study of 2,597 French older adults, increases in time spent using computers was associated with better cognitive performance (Kesse-Guyot et al., 2012). These findings suggest that all sedentary behaviors may not be similarly associated with health risk. Yet, limited research has examined how sedentary behaviors may be categorized into groups, and how categories of sedentary behaviors might be associated with MVPA or aspects of health and well-being. Understanding how different types of sedentary behaviors are related to health is particularly relevant to older adults, who tend to spend longer time sitting and who have greater availability of leisure time after retirement (Clark et al., 2010).

The aim was to identify categories of leisure time sedentary behaviors (LTSBs), and to examine their separate associations with indices of health and well-being among community-dwelling Japanese older adults.

Methods

Participants and data collection

Detailed sampling procedures were described in elsewhere (Inoue et al., 2012). Briefly, this population-based, cross-sectional study was conducted in three Japanese municipalities; Bunkyo Ward in Tokyo, Fuchu City in Tokyo, and Oyama Town in Shizuoka Prefecture. Older adults aged between 65 and 74 years old were randomly selected from the registry of residential addresses of each municipality, which were stratified by gender and age (65-69 years and 70-74 years).

In total, 2,700 community-living older adults were identified. Of those initially identified, 2,046 returned the survey. After data cleaning, the data from 1,701 participants were deemed valid for this study (response rate: 67.3%). Among these respondents, 121 participants who had difficulty performing daily activities assessed by the Japanese 8-item Short-Form Health Survey (SF-8) (Tokuda et al., 2009) were excluded from the present analyses. The final sample size was 1,580. All data were collected from February to March 2010.

This study received prior approval from the Tokyo Medical University Ethics Committee.

Measures

Indices of health and well-being

Body mass index (BMI) was derived from self-reported weight and height. Participants were categorized into normal weight (less than 25 kg.m-2) and overweight (25 kg.m-2 or more). Psychological distress was measured using the K6 scale (Kessler et al., 2003). The K6 scale consists of six items, including an item such as “During past 30 days, how often did you feel nervous ?”. Its response format ranges from 0 (none of the time) to 4 (all of the time), with the total score ranging from 0 to 24. The K6 has been translated into Japanese and its internal consistency (Cronbach’s alpha: 0.849) (Furukawa et al., 2008) and validity (100% sensitivity and 69.3% specificity for screening mood and anxiety disorder) have been reported (Furukawa et al., 2008). Participants were categorized into lower (< 9) and higher (≥ 9) psychological distress by using the recommended cut-off point (Katsuki et al., 2011; Kawakami N, 2002). Self-reported health was assessed using an item from the SF-8 (Tokuda et al., 2009): “Overall, how would you rate your health during the past 4 weeks ?” Participants responded to the statement using a 6-point scale consisting of “excellent”, “very good”, “good”, “fair”, “poor”, and “very poor”. Participants were categorized into “good” [excellent, very good, or good] and “poor” [fair, poor, or very poor] health status. For MVPA, the Japanese version of the

International Physical Activity Questionnaire Short-version was used (Murase, 2002). Participants were asked to report the frequency and duration of three types of physical activity: vigorous-intensity, moderate-intensity (excluding walking), and walking. Total time spent in MVPA including walking was calculated by adding these three activities together. MVPA was dichotomized at the median into lower (≤ 350 min/week) and higher (> 350 min/week). This classification was used because a large proportion of participants (about 75%) reported 150 min/week or more of MVPA, the current recommendation for older adults (Nelson et al., 2007).

Leisure-time sedentary behaviors

Leisure time sedentary behaviors (LTSBs) were determined from participants' self-reported frequency and average duration (minutes/day) over the past 7 days. Participants were asked about five types of LTSBs – television viewing , computer use, reading books or newspapers, listening or talking while sitting, and sitting around. These question items were translated into Japanese from an Australian questionnaire on LTSBs (Salmon et al., 2003). The questionnaire is known to have good test-retest reliability (ICC= 0.56–0.82) and acceptable validity (correlation with a three-day log: r = 0.2–0.4) (Salmon et al., 2003).

Covariates

Age and gender were obtained from the registry of residential addresses of each municipality. Educational attainment (years of education), employment status (working hours per week), and living arrangement (living with others, living alone) were obtained through self-report by each respondent. Participants were categorized according to education (up to high school [< 13 years], college degree or more [≥ 13 years]) and working hours (none or part-time work [< 35 hours/week], full-time work [≥ 35 hours/week]).

Statistical Analysis

Exploratory factor analysis was used to classify these five LTSBs. A non-orthogonal rotation method was employed as extracted factors may be correlated to each other. The number of factors was decided based on Kaiser's Eigenvalue (> 1), scree plot, and the ease of interpretation. For each LTSB category, total sedentary time was calculated and dichotomized using median, as its distribution was expected to be skewed.

Multivariate logistic regressions were employed to calculate the odds ratios (ORs) and 95% confidence intervals (95% CI) of lower MVPA for each category of LTSBs, adjusting for gender, age, municipality, living arrangement, education, and employment status. Additional

187 analysis using a cut-off value of 150 min.wk-1 for MVPA were conducted.

188 Then, multivariate logistic regressions were employed to calculate ORs for indices of
189 poorer health , i.e. overweight, higher psychological distress and lower self-reported health.
190 The ORs of being poorer in health status for higher sedentary time in each LTSB category were
191 calculated, adjusting for gender, age, municipality, living arrangement, education, and
192 employment status (Model 1), then further adjusting for MVPA (Model 2).

193 For sensitivity analysis, logistic regression analyses were repeated after changing the
194 cut-off value between both categories of LTSB. i.e., analyses were performed with different
195 thresholds of passive sedentary time (3 hours/day instead of 1 hour/day) and mentally-active
196 sedentary time (1 hour/day instead of 3 hours/day).

197 Before the multiple logistic regression analyses, we calculated Hosmer-Lemeshow's
198 goodness of fit test, of which the null hypothesis is that the distribution fits the data. All
199 statistical analyses were performed in 2013 by using STATA software (version 12); the level of
200 significance was set at $p< 0.05$.

201

202 **Results**

203 Table 1 shows the characteristics of participants. The sample consisted of 52 % men,
204 and the mean age of participants was 69.5 years. About the same number of participants from
205 each of the three municipalities participated in the study.

206 Factor analysis extracted two factors of LTSBs: one consisting of TV (factor loading:
207 0.45), sitting around (0.38), and listening or talking while sitting (0.30); and, the other
208 consisting of computer use (0.37) and reading books or newspapers (0.31). The former was
209 interpreted as "passive sedentary behavior" and the latter "mentally-active sedentary behavior".
210 The two-factor solution explained 88% of the total variance. Correlation between the two
211 factors was 0.60.

212 Table 2 shows the summary statistics for the categories of LTSBs. On average,
213 participants reported 3.62 hours/day of passive and 1.25 hours/day of mentally-active sedentary
214 behaviors. Television viewing time accounted for 70% of the total passive sedentary time, and
215 three quarters of mentally-active sedentary time was spent for reading books or newspapers.

216 Each behavioral category was dichotomized using the median. For passive sedentary
217 behavior, 3 hours/day or less was categorized as lower, and more than 3 hours/day as higher.
218 For mentally-active sedentary behavior, 1 hour/day or less was categorized as lower, and more
219 than 1 hour/day as higher.

220

INSERT TABLES 1 & 2 ABOUT HERE

Figure 1 shows the adjusted ORs of having lower levels of MVPA for each category of LTSBs. Higher passive sedentary time was associated with higher odds of lower MVPA (OR=1.26, 95%CI: 1.02-1.54), whereas higher mentally-active sedentary time was associated with lower odds of lower MVPA (OR=0.70, 95%CI: 0.57-0.86). An additional analysis using a cut-off value of 150 min.wk-1 for MVPA showed the odds ratios for this definition of 'insufficient' MVPA (less than 150 min.wk-1) to be 1.22 (95%CI=0.96-1.55) for higher passive sedentary time, and 0.59 (0.46-0.75) for mentally-active sedentary time.

Table 3 shows the adjusted odds ratios for indices of the health and well-being for each category of LTSBs. Higher passive sedentary time was associated with a higher odds of being overweight and being higher psychological distress. However, the association between higher passive sedentary time and psychological distress became non-significant after MVPA adjustment in Model 2. Passive sedentary time was not associated with self-reported health. No significant association was found between mentally-active sedentary time and any of these health-related indices. It should be noted that the ORs in Model 1 and 2 were about the same for overweight and higher psychological distress, but some attenuation by MVPA was observed for self-reported health.

INSERT FIGURE 1 and TABLE 3 ABOUT HERE

In sensitivity analysis, changing thresholds of passive sedentary time from 3 hours/day to 1 hour/day did not significantly affect the findings. However, changing the thresholds of mentally-active sedentary time from 1 hour/day to 3 hours/day show differential associations. Older adults in spending more than 3 hours/day (n=123) for mentally-active sedentary time have significantly higher psychological distress (OR=2.23, 95%CI: 1.17 -4.24). Point estimates of other health indices were shifted to positive association between higher mentally-active sedentary time and being overweight (OR=1.23, 95%CI: 0.79 -1.93) and lower self-reported health (OR=1.32, 95%CI: 0.81 -2.17).

Discussion

This study identified two different types of leisure-time sedentary behaviors: one is passive activity including watching TV, talking and just sitting; the other is mentally active,

involving reading or using computer. Passive and mentally-active sedentary times were differently associated with MVPA and health indices among community-dwelling Japanese older adults. Higher passive sedentary time, the majority of which was spent watching TV, was associated with a higher likelihood of being overweight, greater psychological distress, and lower MVPA. In contrast, higher mentally-active sedentary time was positively associated with MVPA, but not associated with any of the health-related attributes. The present study has reported findings that are broadly consistent with those of these previous studies.

Passive sedentary time was associated with overweight, while no such associations were found for mentally-active sedentary time. Both passive and mentally-active sedentary time could involve common physiological mechanisms with sedentary behaviors, such as lower energy expenditure (Newton et al., 2013). It has been shown that light-intensity physical activity is negatively associated with overall sedentary time (Healy et al., 2008), but the relationship may differ between passive and mentally-active sedentary time. Since light-intensity physical activity is known to be beneficial to older adults' health (Buman et al., 2010), future research needs to examine comprehensive behavioral relationships between sedentary behaviors and light, moderate and vigorous physical activity.

In addition, mentally-active sedentary time may involve beneficial processes that mitigate the deleterious impact of sitting for older adults. For example, reading time may provide mental stimulation to that improves cognitive performance capacities, which help older adults to be supportive of other engagements and activity (Cunningham and Stanovich, 2001; Gallucci et al., 2009). Furthermore, computer use may improve social interaction access to health care services (Cotten et al., 2013), and total quality of life (White et al., 1999). There are likely to be health-related benefits from reducing overall sedentary time; however, initiatives to promote older adults' health may most usefully emphasize reducing passive sedentary time.

The sensitivity analysis showed different association between mentally-active sedentary time and health indices. Similar to passive sedentary time, more time in mentally-active sedentary time was negatively associated with health-related attributes. A study among 2,650 middle-aged Australian adults also showed too much computer use was associated with overweight and physical inactivity (Vandelanotte et al., 2009). Therefore, it may be important to avoid spending too much time for both mentally-active sedentary time and passive sedentary time. At the present time, total amount of mentally-active sedentary time is not as long as the amount of passive sedentary time. However, it would be expected that the time spent in computer use is increasing among older adults.

Regarding the association between LTSBs and MVPA, passive sedentary time showed

289 a negative association, suggesting a complementary relationship between these behaviors. In
290 contrast, those who spent longer time in reading and computer use were also likely to engage in
291 longer MVPA. A recent meta-analysis also found the same pattern of relationships (Rhodes et
292 al., 2012). Specific reasons for these differences remain to be explored. It may be the case that
293 mentally-active sedentary time is linked to older adults' social interaction (Cotten et al., 2013),
294 older adults who engage in mentally-active sedentary behavior may have higher social
295 participation, which can involve leisure-time and community activities.
296 Some limitations of our study should be considered. First, all data were collected using
297 self-report measures (van Uffelen et al., 2011). Second, a cross-sectional survey does not allow
298 interpretations of the direction of causality. Reverse causality should be considered, especially
299 for some variables such as BMI and self-reported health. Third, a relatively high proportion
300 (75%) of our study participants reported levels of physical activity that could be classified as
301 sufficient for health benefits. This may represent an over estimate by our participants, or may
302 reflect some form of reporting or social-desirability bias. Fourth, our study did not have data on
303 sitting time in cars, which is a known health risk behavior (McCormack and Virk, 2014). Since
304 about half of the participants were working, this may have confounded the relationships
305 examined in the study. Future studies with such information, as well as information on other
306 components of sedentary time, will help to better understand how multiple domains of
307 sedentary behaviors are related to older adults' health.
308 A strength of our study is that we recruited community-dwelling older adults
309 randomly-selected from three different localities (urban, suburban, and regional), and assessed
310 the association between multiple sedentary behavior and several health-related attributes. The
311 response rate to our survey and the availability of complete data was acceptable (59%). Our
312 findings add important empirical information for targeting specific type of sedentary behaviors
313 for preventing sedentary behaviors-related chronic diseases among older adults, which is
314 particularly important in our aging world.
315
316 **Conclusions**
317 Passive and mentally-active sedentary time may play different roles in the physical and
318 mental well-being of older adults. This findings suggest that passive sedentary behaviors
319 (including TV viewing time), rather than total sedentary time, might have to be targeted in
320 interventions for maintaining and enhancing older adults' health. Future studies need to focus
321 not only on overall sitting time, but also types of sedentary behavior in examining the health
322 impact of sitting. Research seeking to understand mechanisms through which different types of

323 sedentary behaviors influence health is also warranted.

324

Acknowledgements

This study was supported by the Grant-in-Aid for Scientific Research (B): 25282209 from the Japan Ministry of Education, Culture, Sports and Science and Technology. Sugiyama is supported by the National Health and Medical Research Council of Australia (NHMRC) Program funding (#569940). Owen is supported by NHMRC Program Grant (#569940) and a Senior Principal Research Fellowship (1003960). Sugiyama and Owen are supported by the Victorian Government's OIS Program. All authors have no other conflicts of interest, including related directorships, stock holdings, or contracts

336

337 **REFERENCES**

338

339 Buman, M.P., Hekler, E.B., Haskell, W.L., Pruitt, L., Conway, T.L., Cain, K.L., Sallis, J.F., Saelens,
340 B.E., Frank, L.D., et al., 2010. Objective light-intensity physical activity associations with rated
341 health in older adults. Am J Epidemiol 172:1155-65.
342 Chang, P.C., Li, T.C., Wu, M.T., Liu, C.S., Li, C.I., Chen, C.C., Lin, W.Y., Yang, S.Y., Lin, C.C., 2008.
343 Association between television viewing and the risk of metabolic syndrome in a
344 community-based population. BMC Public Health 8:193.
345 Clark, B.K., Sugiyama, T., Healy, G.N., Salmon, J., Dunstan, D.W., Shaw, J.E., Zimmet, P.Z., Owen,
346 N., 2010. Socio-demographic correlates of prolonged television viewing time in Australian men
347 and women: the AusDiab study. J Phys Act Health 7:595-601.
348 Cotten, S.R., Anderson, W.A., McCullough, B.M., 2013. Impact of internet use on loneliness and
349 contact with others among older adults: cross-sectional analysis. J Med Internet Res 15:e39.
350 Cunningham, A.E., Stanovich, K.E., 2001. What reading does for the mind. Journal of Direct
351 Instruction 1:137-49.
352 Dunstan, D.W., Salmon, J., Owen, N., Armstrong, T., Zimmet, P.Z., Welborn, T.A., Cameron, A.J.,
353 Dwyer, T., Jolley, D., et al., 2005. Associations of TV viewing and physical activity with the
354 metabolic syndrome in Australian adults. Diabetologia 48:2254-61.
355 Ford, E.S., 2012. Combined television viewing and computer use and mortality from all-causes and
356 diseases of the circulatory system among adults in the United States. BMC Public Health 12:70.
357 Furukawa, T., Kawakami, N., Saitoh, M., Ono, Y., Nakane, Y., Nakamura, Y., Tachimori, H., Iwata,
358 N., Uda, H., et al., 2008. The performance of the Japanese version of the K6 and K10 in the
359 World Mental Health Survey Japan. Int J Methods Psychiatr Res 17:152-8.
360 Gallucci, M., Antuono, P., Ongaro, F., Forloni, P.L., Albani, D., Amici, G.P., Regini, C., 2009.
361 Physical activity, socialization and reading in the elderly over the age of seventy: what is the
362 relation with cognitive decline? Evidence from "The Treviso Longeva (TRELONG) study". Arch
363 Gerontol Geriatr 48:284-6.
364 Gardiner, P.A., Healy, G.N., Eakin, E.G., Clark, B.K., Dunstan, D.W., Shaw, J.E., Zimmet, P.Z.,

365 Owen, N., 2011. Associations between television viewing time and overall sitting time with the
366 metabolic syndrome in older men and women: the Australian diabetes obesity and lifestyle study.
367 J Am Geriatr Soc 59:788-96.
368 Hamer, M., Stamatakis, E., Mishra, G.D., 2010. Television- and screen-based activity and mental
369 well-being in adults. Am J Prev Med 38:375-80.
370 Hamilton, M.T., Hamilton, D.G., Zderic, T.W., 2007. Role of low energy expenditure and sitting in
371 obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. Diabetes 56:2655-67.
372 Hamilton, M.T., Healy, N.G., Dunstan, D.W., Zderic, T.W., Owen, N., 2008. Too little exercise and
373 too much sitting: Inactivity physiology and the need for new recommendations on sedentary
374 behavior. Current Cardiovascular Risk Reports 2:292-98.
375 Healy, G.N., Wijndaele, K., Dunstan, D.W., Shaw, J.E., Salmon, J., Zimmet, P.Z., Owen, N., 2008.
376 Objectively measured sedentary time, physical activity, and metabolic risk: the Australian
377 Diabetes, Obesity and Lifestyle Study (AusDiab). Diabetes Care 31:369-71.
378 Inoue, S., Sugiyama, T., Takamiya, T., Oka, K., Owen, N., Shimomitsu, T., 2012. Television viewing
379 time is associated with overweight/obesity among older adults, independent of meeting physical
380 activity and health guidelines. J Epidemiol 22:50-6.
381 Jakes, R.W., Day, N.E., Khaw, K.T., Luben, R., Oakes, S., Welch, A., Bingham, S., Wareham, N.J.,
382 2003. Television viewing and low participation in vigorous recreation are independently
383 associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk
384 population-based study. Eur J Clin Nutr 57:1089-96.
385 Katsuki, F., Takeuchi, H., Konishi, M., Sasaki, M., Murase, Y., Naito, A., Toyoda, H., Suzuki, M.,
386 Shiraishi, N., et al., 2011. Pre-post changes in psychosocial functioning among relatives of
387 patients with depressive disorders after Brief Multifamily Psychoeducation: a pilot study. BMC
388 Psychiatry 11:56.
389 Kawakami N, T.A., Shimazu A, Kobayashi Y, 2002. Promotion of preventive measures against
390 suicide in a place of work. (Final report of the National Project Team. Supported by the Research
391 Grant for Industrial Safety and Health (in Japanese)). Ministry of Health, Labour and Welfare.
392 Kesse-Guyot, E., Charreire, H., Andreeva, V.A., Touvier, M., Hercberg, S., Galan, P., Oppert, J.M.,
393 2012. Cross-sectional and longitudinal associations of different sedentary behaviors with

394 cognitive performance in older adults. PLoS ONE 7:e47831.
395 Kessler, R.C., Barker, P.R., Colpe, L.J., Epstein, J.F., Gfroerer, J.C., Hiripi, E., Howes, M.J.,
396 Normand, S.L., Manderscheid, R.W., et al., 2003. Screening for serious mental illness in the
397 general population. Arch Gen Psychiatry 60:184-9.
398 Kronenberg, F., Pereira, M.A., Schmitz, M.K., Arnett, D.K., Evenson, K.R., Crapo, R.O., Jensen,
399 R.L., Burke, G.L., Sholinsky, P., et al., 2000. Influence of leisure time physical activity and
400 television watching on atherosclerosis risk factors in the NHLBI Family Heart Study.
401 Atherosclerosis 153:433-43.
402 McCormack, G.R., Virk, J.S., 2014. Driving towards obesity: A systematized literature review on
403 the association between motor vehicle travel time and distance and weight status in adults. Prev
404 Med 66C:49-55.
405 Murase, N.K., T. Ueda, C. Inoue, S. Shimomitsu, T, 2002. Validity and reliability of Japanese
406 version of International Physical Activity Questionnaire. Journal of Health and Welfare
407 Statistics 49:1-9.
408 Nang, E.E., Salim, A., Wu, Y., Tai, E.S., Lee, J., Van Dam, R.M., 2013. Television screen time, but
409 not computer use and reading time, is associated with cardio-metabolic biomarkers in a
410 multiethnic Asian population: a cross-sectional study. Int J Behav Nutr Phys Act 10:70.
411 Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C., Macera, C.A.,
412 Castaneda-Sceppa, C., 2007. Physical activity and public health in older adults:
413 recommendation from the American College of Sports Medicine and the American Heart
414 Association. Circulation 116:1094-105.
415 Newton, R.L., Jr., Han, H., Zderic, T., Hamilton, M., 2013. The energy expenditure of sedentary
416 behavior: a whole room calorimeter study. PLoS ONE 8:e63171.
417 Owen, N., Healy, G.N., Matthews, C.E., Dunstan, D., 2010. Too much sitting: the population health
418 science of sedentary behavior. Exerc Sport Sci Rev 38:105-13.
419 Owen, N., Sugiyama, T., Eakin, E.E., Gardiner, P.A., Tremblay, M.S., Sallis, J.F., 2011. Adults'
420 sedentary behavior determinants and interventions. Am J Prev Med 41:189-96.
421 Rhodes, R.E., Mark, R.S., Temmel, C.P., 2012. Adult sedentary behavior: a systematic review. Am J
422 Prev Med 42:e3-28.

423 Salmon, J., Owen, N., Crawford, D., Bauman, A., Sallis, J.F., 2003. Physical activity and sedentary
424 behavior: a population-based study of barriers, enjoyment, and preference. Health Psychol
425 22:178-88.
426 Stamatakis, E., Hamer, M., Dunstan, D., 2011. Screen-based entertainment time, all-cause
427 mortality, and cardiovascular events: population-based study with ongoing mortality and
428 hospital events follow-up. J Am Coll Cardiol 57:292 - 99.
429 Sugiyama, T., Healy, G.N., Dunstan, D.W., Salmon, J., Owen, N., 2008. Is television viewing time a
430 marker of a broader pattern of sedentary behavior? Ann Behav Med 35:245-50.
431 Tokuda, Y., Okubo, T., Ohde, S., Jacobs, J., Takahashi, O., Omata, F., Yanai, H., Hinohara, S.,
432 Fukui, T., 2009. Assessing items on the SF-8 Japanese version for health-related quality of life: a
433 psychometric analysis based on the nominal categories model of item response theory. Value
434 Health 12:568-73.
435 van Uffelen, J.G., Heesch, K.C., Hill, R.L., Brown, W.J., 2011. A qualitative study of older adults'
436 responses to sitting-time questions: do we get the information we want? BMC Public Health
437 11:458.
438 Vandelanotte, C., Sugiyama, T., Gardiner, P., Owen, N., 2009. Associations of leisure-time internet
439 and computer use with overweight and obesity, physical activity and sedentary behaviors:
440 cross-sectional study. J Med Internet Res 11:e28.
441 Warren, T.Y., Barry, V., Hooker, S.P., Sui, X., Church, T.S., Blair, S.N., 2010. Sedentary behaviors
442 increase risk of cardiovascular disease mortality in men. Med Sci Sports Exerc 42:879-85.
443 White, H., McConnell, E., Clipp, E., Bynum, L., Teague, C., Navas, L., Craven, S., Halbrecht, H.,
444 1999. Surfing the Net in Later Life: A Review of the Literature and Pilot Study of Computer Use
445 and Quality of Life. Journal of Applied Gerontology 18:358-78.
446
447
448

Table1. Characteristic of study participants

	Total (n=1,580)	
	n or mean	(%) or (±SD)
Gender		
Men	826	(52.3)
Women	754	(47.7)
Age (years)	69.5	(±2.9)
Municipality		
Bunkyo	510	(32.3)
Fuchu	546	(34.6)
Oyama	524	(33.2)
Living arrangements		
Living with others	1,400	(88.6)
Living alone	180	(11.4)
Educational attainment		
College degree or more	991	(62.7)
Up to high school	589	(37.3)
Working hours (hours/week)		
Full-time work (≥35)	646	(40.9)
None or part-time work (<35)	934	(59.1)
BMI (kg/m^2)		
<25.0	1,267	(80.2)
≥25.0	313	(19.8)
Psychological Distress (K6 score)		
Higher (≥9)	94	(5.9)
Normal (<9)	1,486	(94.1)
Self-reported health		
Excellent or good	1,340	(84.8)
Fair or poor	241	(15.3)
MVPA (min/week)		
<350	788	(49.9)
≥350	792	(50.1)

BMI: Body mass index, K6: Kessler's 6-item psychological distress scale
MVPA: Moderate-to-vigorous physical activity
Data are from the cross-sectional survey in 2010 among Japanese older adults (Japan).

Table 2. Time spent in leisure time sedentary behaviors (hours/day)

Types of leisure time sedentary behaviors	Mean	(SD)	Median	(25th-75th percentile)
Passive Sedentary Time	3.62	(2.89)	3.00	(1.64-5.00)
Television or DVD viewing	2.52	(2.12)	2.00	(1.00-3.00)
Listening to music or talking while sitting	0.62	(0.88)	0.33	(0.00-1.00)
Sitting around and doing nothing special	0.47	(1.08)	0.00	(0.00-0.50)
Mentally-Active Sedentary Time	1.25	(1.42)	1.00	(0.43-1.71)
Computer and internet use	0.29	(0.82)	0.00	(0.00-0.14)
Reading books or newspapers	0.94	(1.05)	0.67	(0.33-1.00)

Data are from the cross-sectional survey in 2010 among Japanese older adults (Japan).

Table 3. Associations of health-related attributes with leisure time sedentary behavior categories

			Overweight		Higher psychological distress		Lower self-reported health	
			OR	(95% C I)	OR	(95% C I)	OR	(95% C I)
Passive sedentary time	Model 1	Lower	(1.00)		(1.00)		(1.00)	
		Higher	1.40*	(1.08 - 1.80)	1.55**	(1.00 - 2.39)	1.11	(0.84 - 1.48)
	Model 2	Lower	(1.00)		(1.00)		(1.00)	
		Higher	1.39*	(1.08 - 1.79)	1.53	(0.99 - 2.36)	1.08	(0.81 - 1.43)
Mentally-active sedentary time	Model 1	Lower	(1.00)		(1.00)		(1.00)	
		Higher	0.87	(0.68 - 1.13)	0.76	(0.49 - 1.17)	0.79	(0.59 - 1.06)
	Model 2	Lower	(1.00)		(1.00)		(1.00)	
		Higher	0.88	(0.68 - 1.14)	0.77	(0.50 - 1.20)	0.83	(0.62 - 1.11)

OR: Odds ratio, CI : Confidence interval, * significantly different at $p<0.05$; ** significantly different at $p<0.01$

Model 1: Adjusted for gender, age, municipality, living arrangements, education, and employment status.

Model 2: Adjusted for gender, age, municipality, living arrangements, education, employment status and moderate-to-vigorous physical activity

Data are from the cross-sectional survey in 2010 among Japanese older adults (Japan).

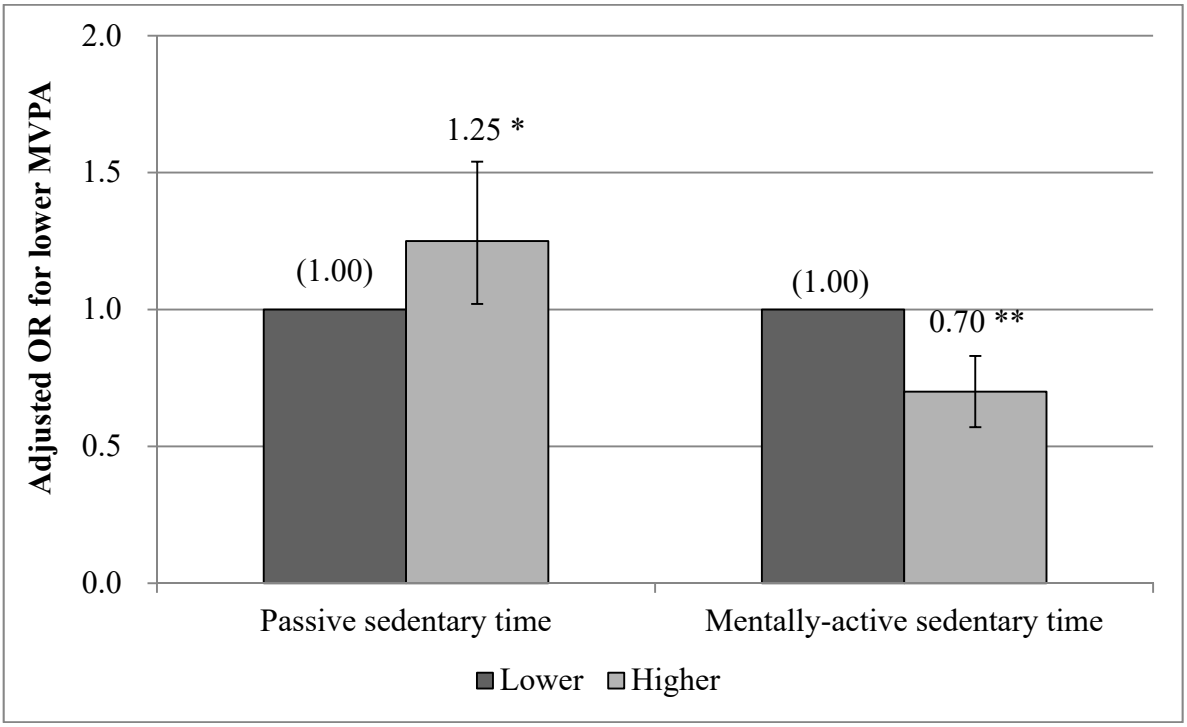

Figure 1. Adjusted ORs and 95% confidence intervals of lower MVPA levels by types of leisure time sedentary behaviors

(MVPA: moderate-to-vigorous physical activity. OR: Odds ratio. All ORs were adjusted for gender, age, municipality, living arrangements, education, and employment status. * $p<0.05$, ** $p<0.01$, Data are from the cross-sectional survey in 2010 among Japanese older adults.)

Disclosure of funding

This study was supported by the Grant-in-Aid for Scientific Research (B): 25282209 from the Japan Ministry of Education, Culture, Sports and Science and Technology. Owen is supported by a National Health and Medical Research Council of Australia (NHMRC) Program Grant (#569940), a Senior Principal Research Fellowship (1003960) and by the Victorian Government's Operational Infrastructure Support program.

Conflict of Interest Statement

The authors declare that there are no conflict of interest.