Psychological and Environmental Correlates of Moderate-to-Vigorous Physical Activity and Step Counts Among Older Adults With Cognitive Decline

Harada, Kazuhiro ; Lee, Sangyoon ; Lee, Sungchul ; Bae, Seongryu ; Harada, Kenji ; Suzuki, Takao ; Shimada, Hiroyuki

(Citation)
Perceptual and Motor Skills,126(4):639-655

(Issue Date)
2019-08

(Resource Type)
journal article

(Version)
Accepted Manuscript

Short title: PSYCHOLOGICAL AND ENVIRONMENTAL CORRELATES OF PHYSICAL ACTIVITY

Psychological and Environmental Correlates of Moderate-to-vigorous Physical Activity and Step Counts among Older Adults with Cognitive Decline

Kazuhiro Harada

Kobe University and National Center for Geriatrics and Gerontology

Sangyoon Lee, Sungchul Lee, Seongryu Bae,

National Center for Geriatrics and Gerontology

Kenji Harada

Chukyo University and National Center for Geriatrics and Gerontology

Takao Suzuki

J. F. Oberlin University

Hiroyuki Shimada

National Center for Geriatrics and Gerontology

Author Note

Kazuhiro Harada, Graduate School of Human Development and Environment, Kobe University and Department of Preventive Gerontology, National Center for Geriatrics and Gerontology; Sangyoon Lee, Department of Preventive Gerontology, National Center for Geriatrics and Gerontology; Sungchul Lee, Department of Preventive Gerontology, National Center for Geriatrics and Gerontology; Seongryu Bae,

Short title: PSYCHOLOGICAL AND ENVIRONMENTAL CORRELATES OF PHYSICAL ACTIVITY

Department of Preventive Gerontology, National Center for Geriatrics and Gerontology; Kenji Harada, Graduate School of Health and Sport Science, Chukyo University and Department of Preventive Gerontology, National Center for Geriatrics and Gerontology; Takao Suzuki, Institute for Gerontology, J. F. Oberlin University; Hiroyuki Shimada, Department of Preventive Gerontology, National Center for Geriatrics and Gerontology.

Correspondence concerning this article should be addressed to Kazuhiro Harada, Graduate School of Human Development and Environment, Kobe University, 3-11, Tsurukabuto, Nada, Kobe City, Hyogo 657-8501, Japan. Tel: +81-78-803-7886 ; Fax: +81-78-803-7886. E-mail address: harada@harbor.kobe-u.ac.jp

Acknowledgments

This work was supported by Strategic Basic Research Programs (RISTEX Redesigning Communities for Aged Society), Japan Science and Technology Agency; the joint research with Kao Corporation; and Grant-in-Aid for Young Scientists B (26750329), Japan Society for the Promotion of Science.

Declaration of Conflicting Interests.

H.S. have received a research grant from the Kao Corporation. The Kao Corporation had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. No other author has reported a potential conflict of interest relevant to this article.

Psychological and Environmental Correlates of Moderate-to-Vigorous Physical Activity and Step Counts among Older Adults with Cognitive Decline

Abstract

Promoting physical activity (PA) among older adults with cognitive decline is important for maintaining and improving their health. Identifying psychological and environmental PA correlates in this population can help develop effective strategies for PA promotion. Since past findings with healthy older adults may not generalize to those with cognitive decline, this study offers data on how self-efficacy, self-regulation, and social-environmental factors were associated with PA among a group of older adults with cognitive decline. We report secondary analysis of baseline data from a separate randomized control study of 262 older participants (*M* = 76.2 years old) who showed a decline in global cognitive function as defined by Mini-Mental State Examination (MMSE) scores between 21 and 24. The participants' PA was measured by an accelerometer, and participants completed questionnaires measuring self-efficacy, self-regulation, social support, social network, and demographic variables. In this study, we evaluated their neighborhood environment with a geographic information system and found through stepwise multiple regression analyses that self-efficacy, gender, and age were associated with PA variables, while self-regulation and environmental factors were not associated with PA variables. Thus, perceived self-efficacy was important psychological correlate of PA in this group of older adults with cognitive decline. PA promotion interventions for this population should attend to these correlates.

Keywords: Aging; Exercise behavior; Exercise motivation; Exercise self-efficacy; Health behaviors

Introduction

It is well established that physical activity (PA) has various health benefits for older adults. Current PA guidelines (World Health Organization, 2010) recommend that healthy older adults engage in at least 150 minutes of moderate-intensity PA per week, or at least 75 minutes of vigorous-intensity PA per week, or an equivalent combination of moderate- and vigorous-intensity PA per week for health promotion. PA also provides health benefits for a common sub-group of older adults – those with cognitive decline. Among community-dwelling older adults without dementia or limitations in activities of daily living, researchers have estimated that 31.4% have mild or global cognitive impairments (Shimada et al., 2016). Older adults with cognitive decline are at higher risk for various health problems, including dementia (Palmer, Wang, Bäckman, Winblad, & Fratiglioni, 2002), physical impairments (Shimada et al., 2016), and psychological distress (Vinkers, Gussekloo, Stek, Westendorp, & van der Mast, 2004). However, even for this subgroup of older adults, PA can improve physical and cognitive function (Suzuki et al., 2013) and enhance overall quality of life (Maki et al., 2012).

In order to develop effective strategies for promoting PA among older adults with cognitive decline, it is essential to identify correlates of PA with this group so that factors enhancing engagement in PA may be increased (Sallis, Owen, & Fotheringham, 2000). Psychological and environmental correlates have been commonly investigated in PA research with other populations (Bauman et al., 2012). Bandura's (1997) social cognitive theory has been recognized as particularly useful for identifying psychological factors of interest to PA researchers (Rhodes & Nasuti, 2011), including self-efficacy and self-regulation. Self-efficacy represents the belief in one's own capabilities to achieve a goal, and self-efficacy is a well-known PA correlate (Bauman et al., 2012). Self-regulation represents skills for controlling one's own emotions and behavior, and a review article described its association with PA as well (Rhodes & Pfaeffli, 2010). Some previous studies have reported self-efficacy and self-regulation correlates with PA, even among older adults (Mudrak, Slepicka, & Elavsky, 2017; Reyes Fernández, Montenegro Montenegro, Knoll, & Schwarzer, 2014; Olson et al., 2017). Additionally, an ecological model of active living (Sallis et al., 2006) has been applied within past PA research (Rhodes, & Nasuti, 2011), highlighting the long term effects that environmental factors can have on large populations. A systematic literature review showed that neighborhood environments help determine PA among older adults (Cerin et al., 2017).

Although various previous studies have examined both psychological and environmental correlates of PA among older adults, previous work has focused on healthier populations with results that may not generalize to older adults with cognitive decline. Cerin et al.'s (2017) review found that the relationships between environment and PA vary with age, sex, living arrangement, health status, and so on. Since some studies have found declining physical function to be a further source of variance (King et al., 2011; Satariano et al., 2010), it is reasonable to expect cognitive functioning to influence these relationships as well. Regarding psychological correlates of PA, Hall, Zehr, Paulitzki, and Rhodes (2014) showed implementation intention (a similar concept to self-regulation) to be linked with PA more closely among older adults with higher cognitive function than among those with lower cognitive function. Hall et al.'s (2014) findings suggest that the influences of psychological factors on PA are apt to differ according to the level of older adults' cognitive functioning. Thus, on an exploratory basis, the present study examined the associations of psychological factors (i.e., self-efficacy and self-regulation), and environmental (i.e., social and neighborhood factors) with PA levels among older adults with cognitive decline.

Method

Participants

The present study was a secondary analysis of baseline PA and questionnaire data gathered within a separate randomized control study of the effects of PA on cognitive functions of a group of older adults with declines in global cognitive function. We registered the protocol of this trial (ID: UMIN000013097) at the website of the UMIN Clinical Trials Registry <http://www.umin.ac.jp/ctr/index.htm>.

We reported the participant recruitment process for this secondary analysis in Harada, Lee et al. (2017). We recruited a sub-cohort of the participants from the

National Center for Geriatrics and Gerontology - Study of Geriatric Syndromes (Shimada et al., 2016) consisting of 5,257 older adults who lived in Midori ward of Nagoya city, aged ≥ 70 years, and were enrolled in this screening survey of physical and cognitive functions. From among these 5,257 participants, we invited 709 as potential participants for this study, as this subgroup met the following inclusion criteria: (a) a decline in global cognitive function, defined as a score between 21-24 on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975); (b) normal gait speed of ≥ 1 meter per second; (c) no serious health problems (stroke, major depression, Parkinson's disease, etc.); and (d) no participation in other intervention studies. Previous studies have treated this range of MMSE scores as mild cognitive decline (e.g., Dodson, Truong, Towle, Kerins, & Chaudhry, 2013; Kovács, Sztruhár Jónásné, Karóczi, Korpos, & Gondos, 2013; Young, Meagher, & Maclullich, 2011). While 359 of these 709 individuals participated in the baseline assessment, 79 were excluded due to withdrawal (n = 24), incomplete data or outlier data (n = 21), detections of health problems at baseline assessment (e.g., new diagnosis of above diseases; n = 27), or frequent participation in PA programs through fitness centers (n = 7). Thus, we first enrolled 280 individuals. Next, we excluded an additional 13 who did not meet a criterion for valid accelerometer data (see more detail below) and excluded another five with missing questionnaire data, leaving 262 participants whose data are reported within this paper. Because we included only individuals with MMSE scores ranging from 21 to

24, the range of these participants' cognitive functioning was limited, and we saw no need to further examine cognitive function in this paper.

Measures

Physical activity. We measured participant step count and the amount of time participants engaged in moderate-to-vigorous PA (i.e., time spent in activities involving ≥ three metabolic equivalents) with a triaxial accelerometer (GT40-020: Kao Corporation: Tokyo, Japan) set at an epoch length of four seconds. We calculated the time in moderate-to-vigorous PA/ day by summing all epochs in one day that contained ≥ three metabolic equivalents. At the end of the baseline assessment of our earlier intervention study, we distributed the accelerometers; and, by this point, the questionnaire surveys had already been completed. Participants had been asked to wear a waist accelerometer throughout the day, including while sleeping but not while bathing, for 14 days from the day following baseline assessment. By asking them to wear the accelerometer even while sleeping, we expected to reduce participant concerns about putting it on and taking it off. The participants did not need to operate this accelerometer as automatically recorded data with a battery life of 6-12 months. We set the display of the accelerometer as "blind," so that the participants would not be able to monitor their own PA levels, and this feedback would not influence their PA behavior. We calculated the actual accelerometer wearing time by subtracting the non-wearing time from 24 hours. To identify valid accelerometer data, we followed guidelines from a systematic review of the uses of the accelerometer to measure PA among older adults (Gorman et al., 2014), suggesting that the most common way to treat accelerometer data is to ask participants to wear the accelerometer for seven days, and to analyze the data if participants wore it for ≥ 10 hours a day for at least four of seven days. Because the participants in our study were asked to wear it for 14 days, we analyzed the accelerometer data if participants wore it for ≥ 10hours in a day for at least eight of 14 days. For each participant, we then calculated the mean number of daily steps taken and the mean number of minutes spent in moderate-to-vigorous PA.

Self-efficacy. The present study used a Japanese scale that measures self-efficacy for exercise (Oka, 2003). This scale assesses one's confidence for maintaining exercise when faced with four common barriers (physical fatigue, poor weather conditions, lack of time, and psychological stress). An item example is "I have confidence to maintain exercise even when I feel psychological stress." The participants answered items on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), and item scores were summed, with higher summed scores representing higher self-efficacy. Oka (2003) confirmed good two-week test-retest reliability ($r = 0.78$) and internal consistency (Cronbach's $\alpha = 0.84$) of this scale, and supported its construct validity (GFI = 0.99, AGFI = 0.97, CF > 0.99, RMSEA = 0.05).

Self-regulation. Self-regulation of exercise was measured by a scale developed by Takeda, Oka, Sakai, and Nakamura (2009). This scale consists of five self-regulation items related to PA: goal setting, self-monitoring, gathering information, stimulus control, and self-reinforcement. An example of an item found in this measure is, “I make realistic goals concerning exercising.” The respondents answered items on a 5-point Likert scale, and answers were summed across the five items with higher scores representing higher self-regulation. The scale’s construct validity (GFI = 0.98, AGFI = 0.95, CFI = 0.97, RMSEA = 0.08) and internal consistency (Cronbach’s α = 0.78) have been confirmed (Takeda et al., 2009).

Environmental factors. We measured social data (i.e., social support for exercise, social network) and neighborhood environments as environmental factors of particular interest. We used a Japanese social support scale for exercise (Itakura, Takeda, Oka, & Nakamura, 2003). This scale contains five items about functional, emotional, and informational social support for exercise; respondents answer the items with a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). We summed scores for all items, and higher summed scores represented higher social support. The scale’s construct validity (GFI = 0.98, AGFI = 0.93, CFI > 0.99, RMSEA = 0.07) and internal consistency (Cronbach’s α = 0.86) have been confirmed (Itakura et al., 2003).

For social network assessment, we used the short-form, Japanese version of the Lubben Social Network Scale (Kurimoto et al., 2011) consisting of six items. Responses were summed into one scale, with higher scores representing larger social networks.

This instrument's internal consistency (Cronbach's α = 0.82), the one-week test-retest reliability (r = 0.92), and concurrent validity with depression (Pearson's r = -0.29) have been established (Kurimoto et al., 2011).

In accordance with the recommended 11 items of the Physical Activity Neighborhood Environment Scale (Sallis et al., 2010), we used the following seven of these, developed though a geographic information system: residential density, access to shops, public transport, sidewalks, access to exercise facilities, crime safety, and traffic safety. Although four other factors (bicycle lanes, seeing active people, aesthetics, and household motor vehicles) were also recommended (Sallis et al., 2010), we did not measure them, because the geographic information related to them was not available in Japan (bicycle lanes, aesthetics) or their objective measurement was difficult (seeing active people, household motor vehicles). We used household density data from the 2010 National Census in Japan to determine residential density. For access to shops, we calculated the number of supermarkets, convenience stores, food shops, and liquor/beverage shops within a 500-meter street network buffer of each participant's home address using a phone number database (*i-Taun-Pegi*, translated as "yellow page"). Public transport indicated road network distances (meters) from each home address to the nearest train station or bus stop. Using a geographic database of sidewalks from *Shosai-chizu* (translated as "detailed map") of the ArcGIS Data Collection (Esri Japan Corporation, Tokyo, Japan), we summed the length of sidewalks within a 500-meter buffer of each participant to obtain the sidewalk measure. For measuring access to exercise facilities, we calculated the number of sports facilities, fitness centers, and parks within a 500-meter buffer. We obtained data regarding sports facilities and fitness centers from *i-Taun-Pegi,* and data regarding parks from *Kokudo-Suchi-Joho* (translated as "National Land Numerical Information," National Spatial Planning and Regional Policy Bureau, Ministry of Land, Infrastructure, Transports and Tourism of Japan). We derived crime and traffic safety numbers from a database of crime and traffic accidents in each elementary school district provided by the Aichi Prefectural Police.

Demographic factors. The present study analyzed gender (male, female), age, years of education, and whether or not participants lived alone as demographic factors.

Data Analyses

First, we calculated Cronbach's alphas to indicate the internal consistencies for self-efficacy, self-regulation, and social support. Next, we calculated Pearson's correlation coefficients between PA variables (steps, minutes in moderate-to-vigorous physical activity per day), psychological variables (self-efficacy, self-regulation), environmental factors (social support, social network, neighborhood), and demographic factors (gender, age, education, and living alone or not). We employed absolute values of correlation coefficients (Zhu, 2012) to interpret the Pearson's correlation coefficient as follows: 0 to 0.19, no correlation; 0.20 to 0.39, low correlation; 0.40 to 0.59, moderate correlation; 0.60 to 0.79, moderately high correlation; ≥ 0.80, high correlation.

Because the present study was exploratory, we conducted stepwise multiple regression analyses to examine the relative weight of these PA correlates for predicting PA. Average step counts and minutes in moderate-to-vigorous PA were treated as the dependent variables, and all psychological, environmental, and demographic factors were examined using the stepwise method. We set statistical significance in the multiple regression analyses at $p < 0.05$. We used the SPSS (version 21.0) for Pearson's correlations and the stepwise multiple regression analyses.

Results

Participant Characteristics

Table 1 shows the participants' characteristics (55.9% men, 44.1% women; 8.8% living alone; *M* age = 76.2 years, *SD* age = 4.1 years; *M* years of education = 11.9, *SD* years of education = 2.6). The frequency distributions of participant step counts and their moderate-to-vigorous PA per day are shown in Figures 1 and 2, respectively (*M* steps /day = 6,721.2, *SD* steps /day = 2974.9; *M* moderate-to-vigorous PA /day = 31.7 minutes, SD moderate-to-vigorous PA /day = 21.1 minutes). On average, respondents had 13.7 (*SD* = 1.0) valid accelerometer days, and wore accelerometers 19 hours and 27 minutes (*SD* = 2 hours 45 minutes) per valid day.

[Insert Table 1 and Figures 1 and 2 about here.]

Psychological, Environmental, and Demographic Correlates with PA

First, participants' Cronbach's alphas were 0.88 for self-efficacy, 0.81 for self-regulation, and 0.81 for social support. Next, Table 2 shows Pearson's correlations between PA variables and psychological, environmental, and demographic factors. Self-efficacy was correlated with PA variables with absolute low correlation levels. The values of correlation coefficients between other factors and PA variables did not reach the cut-off level of absolute low correlation.

[Insert Table 2 about here.]

The stepwise multiple regression analyses revealed that higher self-efficacy, being male, and being of a relatively younger age were associated with higher amounts of step counts and minutes in moderate-to-vigorous PA per day. Other independent variables were not selected in the models by the stepwise method.

[Insert Table 3 and Table 4 about here.]

Discussion

The present study found that, among older adults with cognitive decline, self-efficacy was associated with PA, but self-regulation was not. To the best of our knowledge, this is the first study to examine the association of these potentially modifiable psychological influences on PA within this older adult subgroup. In previous studies of older adults, the relative importance of self-efficacy and self-regulation for predicting PA were not conclusive (Mudrak et al., 2017; Olson et al., 2017; Reyes Fernández et al., 2014). Inconsistencies regarding the relative importance of self-efficacy versus self-regulation might be partially explained by differences in the cognitive functioning of participants in different studies. Because successful self-regulation of PA requires sufficient cognitive function (Buckley, Cohen, Kramer, McAuley, & Mullen, 2014), the influence of self-regulation might be weaker among older adults, especially those with cognitive decline. In contrast, the perceived confidence to retain certain PA behaviors might be more influential for this population due to confidence challenges they experience from loss of cognitive function. The present results suggest that the behavioral mechanisms explaining PA among older adults with cognitive decline may be different from those in other populations and from older adults generally.

In the present study, stepwise multiple regression analyses indicated that none of the environmental factors were correlated with PA variables. The absolute values of Pearson's correlation coefficients between environmental factors with PA variables were all less than 0.20, implying no meaningful correlations (Zhu, 2012). Thus, environmental factors may not be important correlates of PA among older adults with cognitive decline even though previous studies have reported that sufficient social support (Lindsay Smith, Banting, Eime, O'Sullivan, & van Uffelen, 2017) and a larger social network size (Larsen, Strong, & Linke, 2014) are associated with higher levels of

PA among general populations of older adults. For neighborhood environmental factors, a meta-analysis identified various neighborhood environmental correlates of PA among older adults generally, including factors such as access to shops, public transportation, parks, and so on (Cerin et al., 2017). Japanese studies of older adults have also reported that crime (Harada, Park et al., 2017), access to exercise facilities (Tsunoda et al., 2012), and sidewalks (Tsunoda et al., 2012) are correlated with PA. Thus, past findings (Cerin et al., 2017; Harada, Park et al., 2017; Tsunoda et al., 2012) about physical environmental PA correlates among generally or cognitively healthy older adults may not generalize to older adults with cognitive decline. A potential reason for this difference may be that older adults with cognitive decline less accurately recognize their social and physical environments, reducing the influence on PA behavior from these social and physical factors.

Additional replicative research with this sub-group of older adults is needed in order to confirm our variant findings from past research with older adults generally. However, a strength of the present study was our use of objective measurement methods of both environmental factors and PA. Our means of gathering and using accelerometer data were in line with research trends (Gorman et al., 2014), and the mean valid days (13.7 days) and mean valid wearing time (19 hours and 27 minutes) among our participants were not near the cut-off points, suggesting that accelerometer data can be reasonably and feasibly used, even among studies of older adults with cognitive decline.

However, among the limitations of this study are that its cross-sectional design cannot demonstrate causal connections between these associations. Second, we experienced a sampling bias in that our participants were recruited for participation in PA interventions and were likely to have been already motivated to perform PA. Supporting this possibility, compared with a PA prevalence survey for older Japanese adults (Inoue et al., 2011), step counts among participants in the present study were higher. Additionally, we used several inclusion/exclusion criteria that were necessary for the intervention study but may not have been needed for this study. Third, wearing an accelerometer could increase participant motivation and self-regulation toward PA. To understand and minimize these influences, we conducted a questionnaire survey before distributing the accelerometer, set the display of the accelerometer as blind, and asked the participants to wear the accelerometer throughout the study period, including while sleeping (but not while bathing). Fourth, our data were obtained from one community in Japan, and we did not compare our group with other older adults who did not show cognitive decline. Finally, the test-retest reliabilities of the scales used were by research with older adults generally, but have not been confirmed among older adults with cognitive decline.

In conclusion, the present study suggests that while self-efficacy was correlated with PA among older adults with cognitive decline, self-regulation and environmental factors were not correlated with PA. Thus, behavioral mechanisms explaining PA among this population are likely to be different from those in other populations. Among the practical implications of the present study, efforts to enhance perceived self-efficacy (e.g., gradually increasing PA level or providing positive feedback for PA competence) might elevate PA levels among older adults with cognitive decline. Based on our findings, future studies that develop and test effective strategies for PA promotion within this population are needed.

References

Bandura A. (1997). Self-efficacy: The exercise of control. New York, NY: Freeman.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., & Martin, B. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *Lancet*, *380*(9838), 258–271. https://doi.org/10.1016/S0140-6736(12)60735-1

Buckley, J., Cohen, J. D., Kramer, A. F., McAuley, E., & Mullen, S. P. (2014). Cognitive control in the self-regulation of physical activity and sedentary behavior. *Frontiers in Human Neuroscience*, *8*, 747. https://doi.org/10.3389/fnhum.2014.00747

Cerin, E., Nathan, A., van Cauwenberg, J., Barnett, D. W., Barnett, A., & Council on Environment and Physical Activity (CEPA) – Older Adults working group. (2017). The neighbourhood physical environment and active travel in older adults: A systematic review and meta-analysis. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 15. https://doi.org/10.1186/s12966-017-0471-5

Dodson, J. A., Truong, T.-T. N., Towle, V. R., Kerins, G., & Chaudhry, S. I. (2013). Cognitive impairment in older adults with heart failure: prevalence, documentation, and impact on outcomes. *The American Journal of Medicine*, *126*(2), 120–6. https://doi.org/10.1016/j.amjmed.2012.05.029

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state.” A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198.

Gorman, E., Hanson, H. M., Yang, P. H., Khan, K. M., Liu-Ambrose, T., & Ashe, M. C. (2014). Accelerometry analysis of physical activity and sedentary behavior in older adults: A systematic review and data analysis. *European Review of Aging and Physical Activity*, *11*(1), 35–49. https://doi.org/10.1007/s11556-013-0132-x

Hall, P. A., Zehr, C., Paulitzki, J., & Rhodes, R. (2014). Implementation intentions for physical activity behavior in older adult women: an examination of executive function as a moderator of treatment effects. *Annals of Behavioral Medicine*, *48*(1), 130–136. https://doi.org/10.1007/s12160-013-9582-7

Harada, K., Lee, S., Lee, S., Bae, S., Harada, K., Suzuki, T., & Shimada, H. (2017). Objectively-measured outdoor time and physical and psychological function among older adults. *Geriatrics & Gerontology International*, *17*(10), 1455–1462. https://doi.org/10.1111/ggi.12895

Harada, K., Park, H., Lee, S., Shimada, H., Yoshida, D., Anan, Y., & Suzuki, T. (2017). Joint association of neighborhood environment and fear of falling on physical activity among frail older adults. *Journal of Aging and Physical Activity*, *25*(1), 140–148. https://doi.org/10.1123/japa.2016-0082

Inoue, S., Ohya, Y., Tudor-Locke, C., Tanaka, S., Yoshiike, N., & Shimomitsu, T. (2011). Time trends for step-determined physical activity among Japanese adults. *Medicine and Science in Sports and Exercise, 43*(10), 1913–1919. https://doi.org/10.1249/MSS.0b013e31821a5225

Itakura, M., Takeda, N., Oka, K., & Nakamura, Y. (2003). Seijin no undo kodo to undo sosyaru sapoto no kan-kei [Exercise behavior and social support for exercise among adults]. *Woukingu Kenkyu [Walking Research]*, (7), 151–158. (in Japanese)

King, A. C., Sallis, J. F., Frank, L. D., Saelens, B. E., Cain, K., Conway, T. L., … Kerr, J. (2011). Aging in neighborhoods differing in walkability and income: Associations with physical activity and obesity in older adults. *Social Science & Medicine*, *73*(10), 1525–1533. https://doi.org/10.1016/j.socscimed.2011.08.032

Kovács, E., Sztruhár Jónásné, I., Karóczi, C. K., Korpos, A., & Gondos, T. (2013). Effects of a multimodal exercise program on balance, functional mobility and fall risk in older adults with cognitive impairment: a randomized controlled singleblind study. *European Journal of Physical and Rehabilitation Medicine*, *49*(5), 639–48. Retrieved from https://www.minervamedica.it/en/getfreepdf/PwJAmGt83d5FkxLK%252BAlt6F2oJPpNHcwoYl8xyX7c9AezYvQqOL8qEbDGcOyf1CxHsDEjEIKPY3PkVYB26DOwbQ%253D%253D/R33Y2013N05A0639.pdf

Kurimoto, A., Awata, S., Ohkubo, T., Tsubota-Utsugi, M., Asayama, K., Takahashi, K., … Imai, Y. (2011). Nihon-go-ban Lubben Social Newtork Scale tansyuku-ban (LSNS-6) no sakusei to sin-raisei oyobi datosei no kento [Reliability and validity of the Japanese version of the abbreviated Lubben Social Network Scale]. *Nihon Ronen Igakkai Zasshi [Japanese Journal of Geriatrics]*, *48*(2), 149–157. https://doi.org/10.3143/geriatrics.48.149 (in Japanese)

Larsen, B. A., Strong, D., & Linke, S. E. (2014). The association between family and friend integration and physical activity: Results from the NHIS. *International Journal of Behavioral Medicine*, *21*(3), 529–536. https://doi.org/10.1007/s12529-013-9318-x

Lindsay Smith, G., Banting, L., Eime, R., O’Sullivan, G., & van Uffelen, J. G. Z. (2017). The association between social support and physical activity in older adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 56. https://doi.org/10.1186/s12966-017-0509-8

Maki, Y., Ura, C., Yamaguchi, T., Murai, T., Isahai, M., Kaiho, A., … Yamaguchi, H. (2012). Effects of intervention using a community-based walking program for prevention of mental decline: A randomized controlled trial. J*ournal of the American Geriatrics Society*, 60(3), 505–510. https://doi.org/10.1111/j.1532-5415.2011.03838.x

Mudrak, J., Slepicka, P., & Elavsky, S. (2017). Social cognitive determinants of physical activity in Czech older adults. *Journal of Aging and Physical Activity, 25*(2), 196–204. https://doi.org/10.1123/japa.2015-0125

Oka, K. (2003). Tyunen-sya ni okeru undo koudo no henyo dankai to undo serufu-efikasi no kankei [Stages of change for exercise behavior and self-efficacy for exercise among middle-aged adults]. *Nihon Kōshū Eisei Zasshi [Japanese Journal of Public Health]*, *50*(3), 208–15. https://doi.org/10.11236/jph.50.3_208 (in Japanese)

Olson, E. A., Mullen, S. P., Raine, L. B., Kramer, A. F., Hillman, C. H., & McAuley, E. (2017). Integrated social- and neurocognitive model of physical activity behavior in older adults with metabolic disease. *Annals of Behavioral Medicine, 51*(2), 272–281. https://doi.org/10.1007/s12160-016-9850-4

Palmer, K., Wang, H. X., Bäckman, L., Winblad, B., & Fratiglioni, L. (2002). Differential evolution of cognitive impairment in nondemented older persons:

Results from the Kungsholmen project. *American Journal of Psychiatry*, *159*(3), 436–442. https://doi.org/10.1176/appi.ajp.159.3.436

Reyes Fernández, B., Montenegro, E., Knoll, N., & Schwarzer, R. (2014). Self-efficacy, action control, and social support explain physical activity changes among Costa Rican older adults. *Journal of Physical Activity & Health, 11*(8), 1573–1578. https://doi.org/10.1123/jpah.2013-0175

Rhodes, R. E., & Pfaeffli, L. A. (2010). Mediators of physical activity behaviour change among adult non-clinical populations: A review update. *The International Journal of Behavioral Nutrition and Physical Activity*, *7*, 37. https://doi.org/10.1186/1479-5868-7-37

Rhodes, R. E., & Nasuti, G. (2011). Trends and changes in research on the psychology of physical activity across 20 years: A quantitative analysis of 10 journals. *Preventive Medicine*, *53*(1-2), 17–23. https://doi.org/10.1016/j.ypmed.2011.06.002

Sallis, J.F., Owen, N., & Fotheringham, M. J. (2000). Behavioral epidemiology: a systematic framework to classify phases of research on health promotion and disease prevention. *Annals of Behavioral Medicine*, 22(4), 294–298. https://doi.org/ 10.1007/BF02895665

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual*

Review of Public Health, *27*, 297–322. https://doi.org/10.1146/annurev.publhealth.27.021405.102100

Sallis, J. F., Kerr, J., Carlson, J. A., Norman, G. J., Saelens, B. E., Durant, N., & Ainsworth, B. E. (2010). Evaluating a brief self-report measure of neighborhood environments for physical activity research and surveillance: Physical Activity Neighborhood Environment Scale (PANES). *Journal of Physical Activity & Health*, *7*(4), 533–540. https://doi.org/10.1123/jpah.7.4.533

Satariano, W. A., Ivey, S. L., Kurtovich, E., Kealey, M., Hubbard, A. E., Bayles, C. M., … Prohaska, T. R. (2010). Lower-body function, neighborhoods, and walking in an older population. *American Journal of Preventive Medicine*, *38*(4), 419–428. https://doi.org/10.1016/j.amepre.2009.12.031

Shimada, H., Makizako, H., Doi, T., Tsutsumimoto, K., Lee, S., & Suzuki, T. (2016). Cognitive impairment and disability in older Japanese adults. *PloS One*, *11*(7), e0158720. https://doi.org/10.1371/journal.pone.0158720

Shimada, H., Tsutsumimoto, K., Lee, S., Doi, T., Makizako, H., Lee, S., … Suzuki, T. (2016). Driving continuity in cognitively impaired older drivers. *Geriatrics & Gerontology International*, *16*(4), 508–514. https://doi.org/10.1111/ggi.12504

Suzuki, T., Shimada, H., Makizako, H., Doi, T., Yoshida, D., Ito, K., … Kato, T. (2013). A randomized controlled trial of multicomponent exercise in older adults with mild cognitive impairment. *PloS One*, 8(4), e61483. https://doi.org/10.1371/journal.pone.0061483

Takeda, N., Oka, K., Sakai, K., & Nakamura, Y. (2009). Seijin ni okeru undo ni kansuru koudouteki sukiru to undo kodo no hen-yo suteji no kanren [The Relationship between exercise behavioral skills and the stages of change for exercise behavior among Japanese adults]. *Kodo Igaku Kenkyu [Japanese Journal of Behavioral Medicine]*, *14*(1), 8–14. https://doi.org/10.11331/jjbm.14.8 (in Japanese)

Tsunoda, K., Tsuji, T., Kitano, N., Mitsuishi, Y., Yoon, J. Y., Yoon, J., & Okura, T. (2012). Associations of physical activity with neighborhood environments and transportation modes in older Japanese adults. *Preventive Medicine*, *55*(2), 113–118. https://doi.org/10.1016/j.ypmed.2012.05.013

Vinkers, D. J., Gussekloo, J., Stek, M. L., Westendorp, R. G. J., & van der Mast, R. C. (2004). Temporal relation between depression and cognitive impairment in old age: prospective population based study. *BMJ (Clinical Research Ed.)*, *329*(7471), 881. https://doi.org/10.1136/bmj.38216.604664.DE

World Health Organization. (2010). Global recommendations on physical activity for health. Retrieved from http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf

Young, J., Meagher, D., & Maclullich, A. (2011). Cognitive assessment of older people. *BMJ(Clinical Research Ed.), 343*(7822), d5042. https://doi.org/10.1136/bmj.d5042

Zhu, W. (2012). Sadly, the earth is still round ($p < 0.05$). *Journal of Sport and Health Science*, *1*(1), 9–11. https://doi.org/10.1016/j.jshs.2012.02.002

Figure Captions

Figure 1. Frequency distribution of average step counts per day (n = 262).

Figure 2. Frequency distribution of average minutes of moderate-to-vigorous physical activity per day (n = 262).

Table 1
Characteristics of respondents.

	M or %	SD	Range
Physical activity			
Steps/day	6721.2	2974.9	1676.1–21424.9
MVPA/day	31.7	21.1	1.7–154.7
Psychological factors			
Self-efficacy	13.6	3.4	4–20
Self-regulation	14.0	5.0	5–25
Environmental factors			
Social support	17.2	4.3	5–25
Social network	17.3	5.3	3–29
Residential density	3240.8	1386.0	104.5–10179.2
Access to shops	2.8	3.0	0–15
Public transport	277.3	134.5	6.1–777.2
Sidewalks	4476.9	1739.5	533.2–8735.7
Access to exercise facilities	3.1	1.6	0–8
Crime	11.6	5.2	5.9–34.0
Traffic accidents	5.3	2.3	1.7–12.0
Demographic factors			
Gender (male)	55.9%	—	—
Age	76.2	4.1	71–91
Education	11.9	2.6	6–22
Living alone	8.8%	—	—

Note. M, mean; SD, standard deviation; MVPA, moderate-to-vigorous physical activity.

Table 2

Correlations among physical activity, psychological factors, environmental factors, and demographic factors.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Physical activity																
1. Steps/day																
2. MVPA/day	**0.93**															
Psychological factors																
3. Self-efficacy	**0.29**	**0.29**														
4. Self-regulation	0.16	0.14	**0.37**													
Environmental factors																
5. Social support	0.17	0.17	**0.37**	**0.43**												
6. Social network	0.02	-0.03	0.19	0.11	0.19											
7. Residential density	-0.11	-0.11	-0.03	-0.06	-0.08	0.03										
8. Access to shops	-0.01	-0.02	-0.03	0.06	0.00	-0.05	-0.04									
9 Public transport	-0.07	-0.04	-0.03	-0.01	-0.05	0.00	0.12	-0.15								
10. Sidewalks	0.03	0.00	0.02	0.13	0.12	0.03	0.07	**0.44**	**-0.27**							
11. Access to exercise facilities	-0.06	-0.06	0.08	0.07	0.07	-0.01	0.01	-0.03	-0.10	**0.24**						
12. Crime	0.02	0.04	-0.10	-0.05	-0.12	0.00	-0.09	**0.30**	0.13	0.09	-0.19					
13. Traffic accidents	0.01	0.05	-0.11	-0.08	-0.03	-0.06	**-0.21**	0.06	0.13	-0.05	-0.17	**0.49**				
Demographic factors																
14. Gender (male)	0.17	0.17	0.09	0.11	-0.04	-0.04	0.07	-0.03	0.09	-0.12	-0.06	0.09	0.05			
15. Age	-0.15	-0.12	0.13	0.08	-0.10	-0.03	0.01	0.14	-0.04	0.07	0.07	-0.02	-0.08	0.03		
16. Education	0.00	0.02	0.10	0.06	0.02	0.17	0.03	-0.10	0.03	-0.05	0.05	-0.08	0.00	0.13	-0.01	
17. Living alone	0.00	-0.01	-0.05	0.04	-0.08	-0.13	0.12	-0.02	-0.06	-0.03	-0.07	-0.01	-0.02	-0.02	0.05	-0.04

Note. Each value represents a Pearson product-moment correlation coefficient. MVPA, moderate-to-vigorous physical activity.

The absolute values of correlation coefficients (Zhu, 2012) were 0 to 0.19 = no correlation, 0.20 to 0.39 = low correlation, 0.40 to 0.59 = moderate correlation, 0.60 to 0.79 = moderately high correlation, and ≥ 0.80 = high correlation. Bold values represent the value of correlation coefficients as ≥ 0.20 (equal to low correlation or above).

Table 3

Stepwise multiple regression analysis for average steps per day.

	Step 1		Step 2		Step 3	
	Standardized β	p-value	Standardized β	p-value	Standardized β	p-value
Psychological factors						
Self-efficacy	0.29	<0.001	0.31	<0.001	0.30	<0.001
Self-regulation	—		—		—	
Environmental factors						
Social support	—		—		—	
Social network	—		—		—	
Residential density	—		—		—	
Access to shops	—		—		—	
Public transport	—		—		—	
Sidewalks	—		—		—	
Access to exercise facilities	—		—		—	
Crime	—		—		—	
Traffic accidents	—		—		—	
Demographic factors						
Gender (male)	—		—		0.15	0.010
Age	—		-0.19	0.002	-0.19	0.001
Education	—		—		—	
Living alone	—		—		—	

Note. Average steps per day represent the dependent variables.

Step 1, $F(1, 261) = 23.00$ ($p<0.001$), $R^2 = 0.08$.

Step 2, $F(2, 260) = 16.91$ ($p<0.001$), $R^2 = 0.11$. Changes in $R^2 = 0.03$ ($p=0.002$).

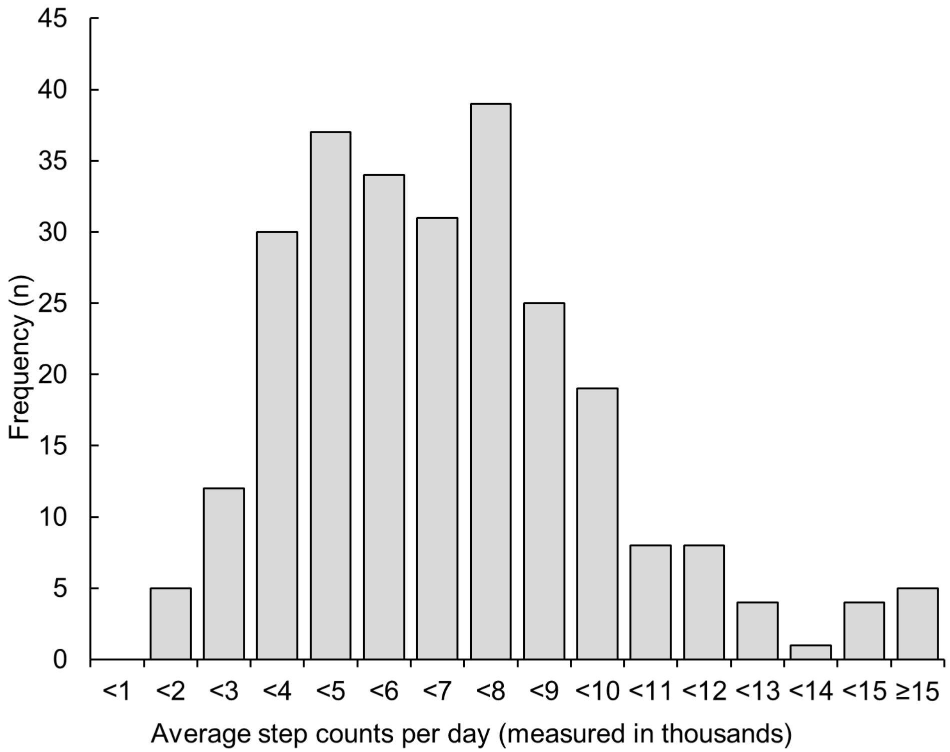
Step 2, $F(3, 258) = 13.80$ ($p<0.001$), $R^2 = 0.14$. Changes in $R^2 = 0.02$ ($p=0.010$).

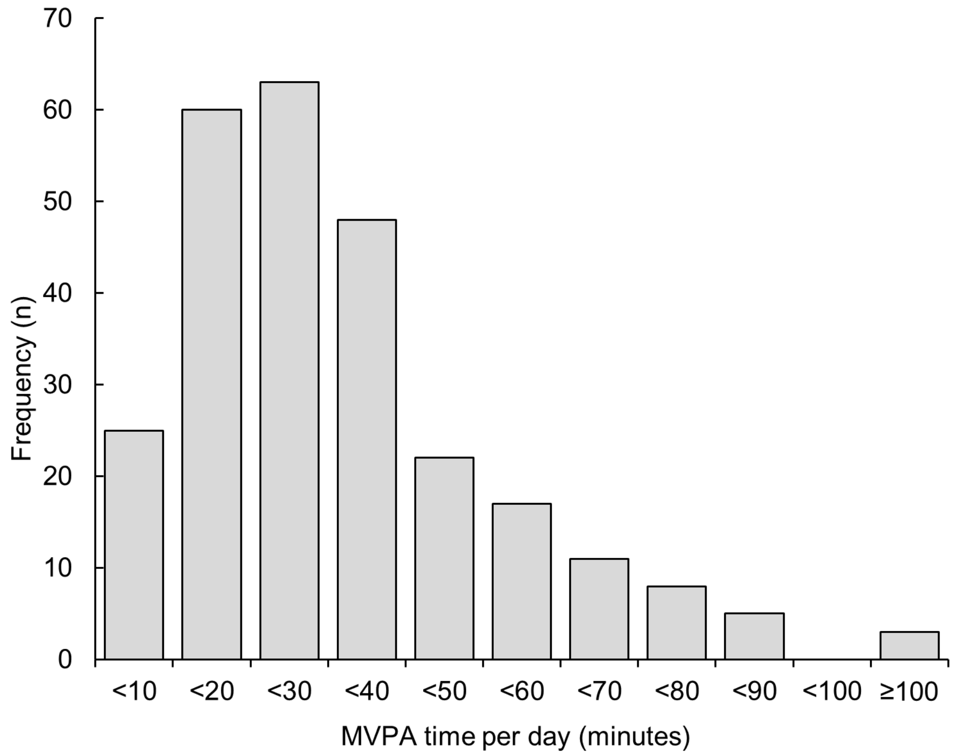
Table 4

Stepwise multiple regression analysis for average moderate-to-vigorous physical activity time per day.

	Step 1		Step 2		Step 3	
	Standardized β	p-value	Standardized β	p-value	Standardized β	p-value
Psychological factors						
Self-efficacy	0.29	<0.001	0.31	<0.001	0.30	<0.001
Self-regulation	—		—		—	
Environmental factors						
Social support	—		—		—	
Social network	—		—		—	
Residential density	—		—		—	
Access to shops	—		—		—	
Public transport	—		—		—	
Sidewalks	—		—		—	
Access to exercise facilities	—		—		—	
Crime	—		—		—	
Traffic accidents	—		—		—	
Demographic factors						
Gender (male)	—		—		0.15	0.011
Age	—		-0.16	0.008	-0.16	0.006
Education	—		—		—	
Living alone	—		—		—	

Note. Average moderate-to-vigorous physical activity time per day represents the dependent variable.
MVPA, moderate-to-vigorous physical activity
Step 1, $F(1, 261) = 24.15$ ($p<0.001$), $R^2 = 0.09$.
Step 2, $F(2, 260) = 15.96$ ($p<0.001$), $R^2 = 0.11$. Changes in $R^2 = 0.03$ ($p=0.008$).
Step 2, $F(3, 258) = 13.04$ ($p<0.001$), $R^2 = 0.13$. Changes in $R^2 = 0.02$ ($p=0.011$).


45
40
35
30
25
20
15
10
5
0
Frequency (n)
<1 <2 <3 <4 <5 <6 <7 <8 <9 <10 <11 <12 <13 <14 <15 ≥15
Average step counts per day (measured in thousands)



70
60
50
40
30
20
10
0
Frequency (n)
<10
<20
<30
<40
<50
<60
<70
<80
<90
<100
≥100
MVPA time per day (minutes)