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(Citation)
Aging & Mental Health,25(12):2235-2245

(Issue Date)
2021-12-02

(Resource Type)
journal article

(Version)
Accepted Manuscript

# Three-year Effects of Neighborhood Social Network Intervention on Mental and Physical Health of Older Adults

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**Funding Details**

This work was supported by Grant-in-Aid for Scientific Research A (24240093), Japan Society for the Promotion of Science; Grant-in-Aid for Scientific Research B (15KT0006), Japan Society for the Promotion of Science; Grant-in-Aid for Challenging Research (18H05298), Japan Society for the Promotion of Science; a Grant from a Community Development Partnership between Kobe University and Nada ward, Kobe City; and Graduate School of Human Development and Environment Grant-in-Aid for Young Scientists, Kobe University.

**Disclosure of Interests**

The authors report no conflict of interest.

**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author, K. Harada, upon reasonable request.

**Acknowledgements**

We would like to thank Editage (www.editage.com) for English language editing.

# Three-year Effects of Neighborhood Social Network Intervention on Mental and Physical Health of Older Adults

**Objectives:** Although neighborhood is considered to be a crucial source of social network to promote health among older adults, current findings are mostly derived from observational study designs. This study examined whether participations in event-based community programs could increase neighborhood social network and whether such increase could lead to desirable changes in mental and physical health among older adults. **Method:** This study employed quasi-experimental design. A baseline questionnaire survey was sent to residents of Tsurukabuto community aged 60 years or more (n = 1769); 1,068 responded. Community events were implemented approximately once a month for three years. Then, a three-year follow-up survey questionnaire was sent to the respondents of the baseline survey. The total number of respondents in the latter survey was 662; of the total, 173 participated in the intervention. Strong and weak ties with neighbors, mental well-being (Ikigai-9), health-related quality of life (HRQOL), and instrumental activity of daily living (IADL) were measured in the surveys. **Results:** The path analysis revealed that intervention participation was significantly associated with changes in strong ties (standardized path coefficient = 0.12) and changes in strong ties were associated with those in Ikigai-9 scores (standardized path coefficient = 0.15). The total and indirect effects of intervention participation on Ikigai-9 scores were significant. Significant intervention effects were not observed for HRQOL and IADL scores. **Conclusion:** This study found that participation in our event-based intervention could indirectly and positively influence older adults' mental well-being through their strong ties with their neighbors.

Keywords: Social Support; Quality of Life/ Wellbeing; Psychosocial Interventions; Physical Health Status

## Introduction

Better social relationships among older adults contribute to improvement in their mental and physical health status. Social relationships consist of functional and structural aspects. Social support reflects a functional aspect of social relationships, whereas social network, which represents the structural aspect, refers to connections and ties between individuals (Holt-Lunstad & Uchino, 2015). The presence of a social network does not

necessarily equate to it being functional. Nonetheless, meta-analyses have shown that both functional and structural aspects of social relationships are associated with mental well-being (Pinquart & Soensen, 2000), cognitive function (Kuiper et al., 2016), the risk of getting coronary heart disease and stroke (Valtorta et al., 2016), and mortality risk (Holt-Lunstad et al., 2010). The desirable effects of a social network on mental and physical health differ depending on its various sources. Previous studies have indicated that neighborhood is a crucial source of social network in promoting mental and physical health among older adults. The impacts of social networks with friends/neighbors on depression (Litwin, 2011), instrumental activity of daily living (Li & Zhang, 2015), and mortality risks (Santini et al., 2015) are more remarkable than those of social networks with families. While the present study focused on the neighborhood social network, referring to social capital studies would be meaningful because social capital studies have also illustrated the importance of neighborhood social network. Social capital is a key concept in public health and social epidemiology, and conceptually has various dimensions such as bounding, bridging, and linking social capital (Islam et al., 2006; Moore & Kawachi, 2017). Neighborhood social network can be regarded as one measure of bonding social capital, which refers to social relationships within homogeneous groups such as family members, neighbors, close friends, etc. (Islam et al., 2006; Moore & Kawachi, 2017). Social capital studies have showed that after adjusting for social network at the individual level, social network at the community level is associated with mental health status at the individual level, such as dementia symptoms (Muayama et al., 2018) and life satisfaction (Inaba et al., 2015).

However, the current findings on the desirable influences of neighborhood social network on health promotion are mostly derived from observational study designs. Only few intervention studies have confirmed such influences. To establish a link between neighborhood social network and health among older adults, evidence from both

observational and interventional studies are essential; the latter can ascertain the causalities of the link by investigating whether an increase in neighborhood social network results in the promotion of health status among older adults. Previous intervention studies targeting social relationships among older adults have not necessarily reported positive changes in health variables. While social capital studies have indicated that promoting social capital at neighborhood levels would be feasible (Chiu et al., 2007; Grant, 2001; Kleinhans et al., 21007), they have not examined the interventional effects of promoting the social capital on health variables. For the social relationships at individual levels, review articles (Dickens et al. 2011; Poscia et al., 2018) have showed that certain interventions have succeeded in increasing social relationship variables among older adults. As the review articles (Dicken et al., 2011; Poscia et al., 2018) have not limited the specific types of interventions, various types of interventions were included in their reviews. The examples of the interventions were a reminiscence program led by a psychologist (Gaggioli et al., 2014), an online program (Jones et al., 2015), a social and recreational activity program (Low et al., 2015), the use of a companion robot (Robinson et al., 2013), and a group-based activity program (Saito et al., 2012). However, according to the review articles, it is still inconclusive whether desirable changes in social relationship variables induced by the intervention can translate into the promotion of health status because previous studies have reported both significant and non-significant results for such translating effects. Dicken et al. (2011) found that 5 of the 12 interventions that showed a significant increase in any social relationship variable but failed to lead desirable changes in mental and/or physical health status among older adults. Similarly, Poscia et al. (2018) showed that two of the six interventions they reviewed reported non-significant changes in health variables, despite significant desirable changes in social relationships variables. Moreover, few previous studies have examined indirect effects of the interventions on health variables mediated by the changes in social relationships. For

example, although all six interventions reviewed by Poscia et al. (2018) examined the total effects of the interventions, they did not investigate the process of translating the effects of intervention on health status mediated by social relationships (Gaggioli et al., 2014; Jones et al., 2015; Low et al., 2015; Robinson et al., 2013; Saito et al., 2012). The process of intervention effects can be conceptualized as one in which interventions do not have direct influences on health status but, rather, manipulate social relationships, which, in turn, influence social relationships that cause changes in health status. By investigating this process, the causal link between social relationships and health status can be strengthened. We consider that the lack of the investigation on this process is an important challenge for the research area of social relationships and health.

Given these findings, we developed and implemented an event-based community program using a university resource. The logic of the event-based community program was to create many opportunities to meet and talk with neighbors, which contribute to improving neighborhood social network. Participation in community events can be regarded as one type of social participation (Levasseur et al., 2010). Thus, the framework for the pathway from social participation to health would be helpful in ascertaining the theoretical basis of the process of our intervention effects. Social participation is associated with various health outcomes of older adults, such as loneliness (Niedzwiedz et al., 2016), depression (Wang et al., 2020), instrumental activities of daily living (Tomioka et al., 2017), and functional disability (Otsuka et al., 2018). Regarding the mechanisms of these associations, previous studies have proposed that social participation influences health through several pathways such as enhancing health literacy (Amoah, 2018), accumulating physical activity (Kikuchi et al., 2017), promoting self-management behavior (Ang, 2019), and gaining better social relationships (Li et al., 2018; Lin et al., 1999). As for the pathway of social relationships, conceptual models (Li et al., 2018; Lin et al., 1999) consider that social participation can

induce better social relationships, and that better social relationships can promote health. Supporting these models, Mackenzie & Abdulrazaq (in press) reported that social network mediates the relationship between social participation variables and mental health status among older adults. The conceptual models of the pathways of social relationships (Li et al., 2018; Lin et al., 1999) and reports from Mackenzie & Abdulrazaq (in press) correspond with the process of our intervention effects. Because getting older is associated with higher risks of geriatric syndrome (Makizako et al., 2017), decline in social relationships with friends (Shaw et al., 2007), and lower levels of social participation (Bukov et al., 2002), promoting participation in community events would be beneficial. In Harada et al. (2018), we analyzed one year of follow-up data and reported that the program can enhance neighborhood social networks of older adults. Although previous studies have employed various types of interventions to increase social relationships among older adults, none of the previous intervention studies have utilized event-based community programs. Thus, our study proposes a new option of intervention type for increasing social relationships among older adults, however, we did not examine any health impacts of the intervention. Therefore, the present study examined whether the intervention participation could augment neighborhood social network at the third year of the follow-up study and whether the increases in neighborhood social network could lead to desirable changes in mental and physical health among older adults. The link between neighborhood social network and health is still unestablished because few social network interventions have examined the pathway from intervention participation to the health status of older adults. The present study contributes to the establishment of such a link by showing the pathway.

## Methods

### *Participants and Procedures*

The present study reported the effects of the "Tsurukabuto Active Aging Project" over a three-year period. The overview of the project is also available in Harada et al. (2018). The project employed a non-blinded quasi-experimental design. The field of the project was Tsurukabuto community, Nada ward, Kobe City, Japan. There are about 5,000 people in Tsurukabuto community (with an area of 0.6 km2), 130,000 in Nada ward (area: 32.7 km2), and 1.5 million in Kobe City (area: 552.3 km2). Tsurukabuto community was developed by cutting a mountain from the 1960s to the 1970s. Compared to the population ageing rate of Nada ward and Kobe city in 2015 at 24.6% and 26.8%, respectively, the Tsurukabuto community saw an ageing rate of 37.1%, which was remarkably high. This is because those who have lived in this community since the 1960s and 70s have reached the age of 65 years or above now. Regarding the other characteristics of this community, as 27.7% participants from Kobe City, 32.9% from Nada Ward, and 32.5% from the Tsurukabuto community completed their college education (4-years or more) (Statistics Bureau of Japan, 2011), the residents of the community generally had an intermediate socio-economic status. Of the participants, 77.7% from Kobe City, 71.7% from Nada Ward, and 79.6% from the Tsurukabuto Community had lived the same residence for at least five years (Statistics Bureau of Japan, 2016), and residential mobility in the Tsurukabuto Community was slightly lower than that of Nada Ward and Kobe City. Furthermore, 54.4% of participants from Kobe City, 65.3% from Nada Ward, and 84.5% from the Tsurukabuto Community lived in apartment houses (Statistics Bureau of Japan, 2016). Thus, the majority of residents in the Tsurukabuto Community live in apartment houses. It can be assumed that many of the residents in this community would not have a sufficient neighborhood social network because this community

153 is not the hometown for all of the older residents. Based on these facts, this community was
154 the target for this project.
155 Figure 1 represents the flow diagram for examining the three-year effect of the project.
156 We sampled all residents of the Tsurukabuto community aged ≥60 years (N = 1,769) from the
157 electoral register in Nada ward. A baseline questionnaire survey was sent to them via postal
158 mail in November 2013; 1,068 of them (61.8%) responded. After the baseline survey, the
159 project implemented the intervention program. In January 2017, 1,021 respondents of the
160 baseline survey, which excluded 47 who had died, were asked to answer a three-year follow-
161 up questionnaire survey via postal mail. Of the 1,021 baseline respondents, 686 (67.2%)
162 responded to the three-year follow-up survey. The latter survey included a question on
163 whether they had participated in the intervention program answered by a "yes" or a "no"; 662
164 individuals answered this item. Among these 662 individuals, the present study treated the
165 173 who answered "yes" as participants of the intervention and the 489 who answered "no" as
166 non-participants.
167 As all eligible residents of Tsurukabuto community were targeted in the project, no
168 prior sample size calculation was conducted.
169 Informed consent was obtained from all respondents of the survey. The Tsurukabuto
170 Active Aging Project received prior approval from the ethical committee of the Graduate
171 School of Human Development and Environment, Kobe University. All procedures were
172 carried out in accordance with the Helsinki Declaration.
173 The Tsurukabuto Active Aging Project was not preregistered anywhere.

174 ***Intervention Program***
175 The project provided event-based intervention programs to residents of Tsurukabuto
176 community. For the mechanisms of the interventions, the present study assumed that the
177 participation in intervention programs would indirectly influence neighborhood social

network mediated by several steps (Harada et al., 2018). First, participation in the programs might provide opportunities for participants to communicate with their neighbors during the programs. Second, such opportunities during the programs would facilitate social interactions in their daily lives outside the programs. Lastly, facilitated social interactions might result in reinforcement of the neighborhood social network. Harada et al. (2018) described the detailed process of developing the programs. The project developed the intervention programs through discussions in three community meetings. Since November 2013, the project had implemented community events approximately once a month: 3 events in 2013, 15 in 2014, 9 in 2015, and 10 in 2016. Most of the events were offered on weekends. Examples of the events are musical entertainment, lecture about sleep and health promotion, moon viewing academic festival, gardening class, and group walking. Kobe University staff members organized all the events. The facilities of Kobe University were used as venues. When recruiting participants for each event, flyers were posted on all houses in Tsurukabuto community. Each event was advertised through the residents' association and university's homepage. Residents of Tsurukabuto community could participate in any event for free. While most programs accepted all residents, the project organized the programs by regarding older adults as the main audience. For some programs such as group walking, the project accepted those above 60 years. The present study did not measure attrition rate of the intervention programs because the intervention programs were event-based and the project recruited different participants for each event.

The event-based programs were intended to increase opportunities for interaction among older adults, which was expected to result in reinforced neighborhood social network. Therefore, each event was organized to facilitate social interactions in various ways. For example, at the beginning of each event, project facilitators explained that the event was aimed to increase social networks in Tsurukabuto community and asked them to get to know

one another. Typically, project facilitators asked participants to wear nametags. As much as possible, the events included interactive activities, such as group work, games, and discussions. Our previous study confirmed that participation in our events could facilitate social interaction among participants (Masumoto et al., 2017).

## ***Measures***

### *Neighborhood Social Network*

Similar to our secondary analysis of the data obtained from the project (Fukuzawa et al., 2019), the present study measured two subtypes of neighborhood social network: strong ties (close people) and weak ties (acquaintances). The respondents were asked the question "How many people do you have relationships with in the Tsurukabuto community ?", and the respondents indicated the specific number of the residents in the community (a) with whom they joined to engage in neighborhood activities together, (b) who they helped together in any problems, (c) who they visited at home, (d) who they greeted, and (e) with whom they talked and chatted (Fukuzawa et al., 2019). Items (a), (b), and (c) reflect strong ties, while items (d) and (e) reflect weak ties (Fukuzawa et al., 2019). The mean number for the three strong-tie items and two weak-tie items were treated as scores of strong ties and weak ties, respectively. As reported in Fukuzawa et al. (2019), the project developed these items with reference to Harper (2002) and Takagi et al. (2010). Among various dimensions of social network such as frequency of contact, density, duration (Berkman et al., 2000), these items measured the size of the neighborhood social network. Cronbach's alphas for the items of strong ties were 0.79 in baseline and 0.81 in the three-year follow-up survey (Fukuzawa et al., 2019). Pearson's correlation coefficient for the items of weak ties were 0.94 in baseline and 0.75 in the three-year follow-up survey (Fukuzawa et al., 2019).

*Mental and Physical Health*

The present study analyzed mental well-being and the mental component of health-related quality of life (HRQOL) as indices of mental health. The physical component of HRQOL and instrumental activity of daily living (IADL) were treated as indices for physical health.

Mental well-being was measured using the Ikigai-9 scale (Imai et al., 2012). This scale consisted of nine items, such as "I often feel that I am happy" and "My daily lives are meaningful." The individuals responded to each item on a 5-point Likert scale, ranging from 1 (very much) to 5 (not at all). Following Imai et al. (2012), the score was calculated by summing the answers of each item. The scale's concurrent validity (Pearson's correlations with mental health scale, $r = 0.33$, $p < 0.01$), factorial validity (Goodness of Fit Index [GFI]= 0.95, Comparative Fit Index [CFI]= 0.95, Root Mean Square Error of Approximation [RMSEA]= 0.09), and internal consistency (Cronbach's alpha = 0.87) were reported in Imai et al. (2012).

The project employed the Japanese version of the Medical Outcomes Study Short Form 8-Item Health Survey (SF-8: Fukuhara & Suzukamo, 2004) to assess the HRQOL. The answers of each item in SF-8 were transformed into standardized scores by using the normative values of the general Japanese population (Fukuhara & Suzukamo, 2004). Then, the summary scores (range, 0 to 100; mean [standard deviation] in national sample, 50 [10]) were calculated for the physical and mental components of health using a standardized calculation formula (Fukuhara & Suzukamo, 2004). The formula was developed based on the results of the factor analyses in the previous study (Fukuhara & Suzukamo, 2004). The alternate form reliability of SF-8 ($r = 0.70$ to 0.88) and correlation with SF-36 ($r = 0.56$ to 0.87) were reported in Fukuhara and Suzukamo (2004).

IADL was measured using the subscale of the Tokyo Metropolitan Institute of Gerontology Index of Competence. Koyano et al. (1991) confirmed the reliability and validity of this index: the Cronbach's alpha was 0.91; one-year test-retest reliability was 0.86, the

model's indices for confirmatory factor analysis were adequate (GFI = 0.95; Root Mean Square Residual [RMSE]= 0.04); the odds ratio for predicting one-year mortality was 1.22 for every 1 point decrease. Among these indices, the IADL subscale consisted of five items; in each item, "yes" and "no" answers corresponded to 1 and 0 point, respectively. The score was calculated by summing the points of each item (Koyano et al., 1991).

*Total Number of Intervention Participation*

In the three-year follow-up survey, participants of the intervention program were asked to indicate the total number of times they participated in the events.

*Demographic Factors*

The present study analyzed the baseline data for age, gender (men, women), educational background (middle to high school, higher than high school), living arrangement (alone, with spouse, in a multigenerational household), and current working status (no, yes) as demographic factors, because previous studies have reported that age (Fujiwara et al., 2008), gender (Pinquart & Sörensen, 2001), educational background (Huang et al., 2010), living arrangement (Sarwari et al., 1998), and current working status (Minami et al., 2015) are associated with the health status of older adults.

## ***Analyses***

*Main Analyses*

Participation in the intervention program (0 = non-participants, 1 = participants) was treated as the independent variable. Using this variable, the present study conducted linear mixed models and a path analysis as the main analyses. The liner mixed model examined the total effects of the intervention participation on neighborhood social network and metal and physical health. As the present study assumed that intervention participation would indirectly

influence mental and physical health status through neighborhood social network, direct and indirect relationships among these variables were examined using path analysis. Similar to previous studies (Cavallo et al., 2014; Gunnell et al., 2014), the path analysis examined residualized change scores as changes in the neighborhood social network and mental and physical health variables in the three-year follow-up survey. The predicted value of the three-year follow-up survey was obtained by first regressing the baseline value and then calculating the residualized change score by subtracting the predicted value from the actual value. While the linear mixed models can examine the time fixed effects, it would be inconvenient to show the direct and indirect effects clearly. The path analyses using the residualized change scores are useful to examine direct and indirect effects of the intervention participation though our path analyses did not include time fixed effects. Thus, conducting both the analyses could supplement each other. The missing values were treated by pair-wise deletion. Statistical significance was set at $< 0.05$.

In the linear mixed models, the dependent variables were strong ties, weak ties, mental well-being, HRQOL, and IADL. Group (0 = non-participants, 1 = participants), survey time (0 = baseline survey, 1 = three-year follow-up survey), and the interaction of group and survey time were treated as the independent variables. The interaction term represented the total intervention effects on the dependent variable. Examining these interaction terms is known as the difference-in-difference approach. This approach considers baseline differences between the two groups and natural time trends, and is widely accepted to show causal inference in quasi-experimental studies (Dimick & Ryan, 2014; Wing et al., 2018). This approach compares the difference over time (follow-up minus baseline) of the intervention group with the difference over time (follow-up minus baseline) of the control group. If the difference over time of the intervention group is significantly different from the difference in the control group, it indicates that the intervention has an effect. In the statistical model, the

300 interaction term of group with time represents such difference-in-difference (Dimick & Ryan,
301 2014; Wing et al., 2018). Age, gender (men = 0, women = 1), educational background
302 (middle to high school = 0, higher than high school = 1), dummy variables of living
303 arrangement, and current working status (no = 0, yes = 1) were included as covariates.
304 Dummy variables of living arrangement were treated as living alone (no = 0, yes = 1) and
305 living with spouse (no = 0, yes = 1). Maximum likelihood estimation was used to fit the
306 model. The mixed command of Stata version 14 (StataCorp LLC, College Station, Texas, the
307 United States) were used.
308 For the path analyses, the present study calculated GFI, adjusted goodness of fi index
309 (AGFI), CFI, and RMSEA as indices of model fit. The present study examined the main paths
310 in the model as follows: 1) paths from the intervention participation to the strong and weak
311 ties; 2) paths from the intervention participation to mental well-being, two components of
312 HRQOL, and IADL; and 3) paths from the strong and weak ties to mental well-being, two
313 components of HRQOL, and IADL. This study included the three types of main paths in the
314 model regardless of their statistical significance. To adjust for potential confounding effects
315 of demographic factors, the model also included statistically significant paths from age,
316 gender, educational background, dummy variables of living arrangement, and current working
317 status to the intervention participation, the strong and weak ties, mental well-being, two
318 components of HRQOL, and IADL. Statistically non-significant paths from these
319 demographic factors were removed from the model. Correlations within demographic factors,
320 between strong and weak ties, and within mental well-being, two components of HRQOL,
321 and IADL were also included in the model if correlations were statistically significant. This
322 study removed statistically non-significant correlations from the model. The bias-corrected
323 bootstrap method (1,000 bootstrap samples) was used to estimate standardized direct, indirect,
324 and total effects, and 95% confidence intervals of the intervention participation on the

neighborhood social network and mental and physical health in the pass model. The AMOS version 21.0 (IBM Japan, Ltd., Tokyo, Japan) was used.

*Additional Sensitivity Analyses*

To confirm the robustness of the main analyses, this study conducted further linear mixed models and path analysis by setting the total number of intervention participation as the independent variable. Therefore, while the main analyses treated the independent variable as a dichotomous variable, additional sensitivity analyses treated it as a continuous variable. Data from non-participants in the intervention was coded as 0 for the total number of intervention participation. The procedures of both linear mixed models and path analysis were the same as those of main analyses.

## Results

### *Participants' Baseline Characteristics*

Table 1 presents participants' baseline characteristics. Participants' mean age at baseline was 72 years old. About 56.3% were women; 45.6% had an educational degree higher than high school; 20.5% lived alone and 53.0% lived with their spouse; and 26.3% were engaged in work. Compared with non-participants, the t-tests and chi-squared tests showed that intervention participants were more likely to be younger, have obtained an educational degree higher than high school, and have higher scores for strong and weak ties, HRQOL physical component, and IADL.

### *Total Effects of Intervention Participation on Neighborhood Social Network and Mental and Physical Health in Mixed Model*

Table 2 presents the overall effects of intervention participation on neighborhood social network and mental and physical health. Although the effect on weak ties was not supported, the liner mixed model showed statistically significant intervention effect on strong ties (p =

0.031). Among four variables for mental and physical health status, intervention effect was observed in mental well-being, with a threshold level of 0.050 for statistical significance.

### *Direct and Indirect Effects of Intervention Participation on Neighborhood Social Network and Mental and Physical Health in Path Analysis*

The path analysis (Figure 2) showed that participation in the intervention was statistically significantly associated with increased changes in strong and weak ties, and that increased changes in strong ties were associated with those in mental well-being. Dummy variables of living arrangement were removed from the model because all paths from it to strong ties, weak ties, mental well-being, HRQOL, and IADL were not statistically significant. The correlation coefficients for all variables in the path model are shown in Supplemental Table 1. The direct path from intervention participation to changes in mental well-being was not statistically significant. Changes in both strong and weak ties were not statistically significantly associated with changes in HRQOL and IADL.

Table 3 shows the direct, indirect, and total effects of intervention participation on neighborhood social network and mental and physical health in the path analysis. The intervention participation had statistically significant indirect and total effects on mental well-being through neighborhood social network. The intervention participation also had direct effects on strong and weak ties. Any direct, indirect, and total effects of the intervention participation on HRQOL mental component, HRQOL physical component, and IADL did not show statistically significant levels.

### *Effect of Number of Intervention Participation on Neighborhood Social Network and Mental and Physical Health*

The average number of intervention participation was 0.78 times (SD = 2.00) among all respondents and was 3.09 times (SD = 2.97) among those who participated in the intervention at least once. The results of the linear mixed models are presented in Supplemental Table 2.

The linear mixed models showed that the interactive effect of the total number of intervention participation and survey time on strong ties was statistically significant. Supplemental Figure 1 illustrates the results of post hoc analysis for strong ties by categorizing the total number of intervention participation into five groups (0 time, 1 time, 2 to 3 times, 4 to 5 times, and 6 or more times). For other variables, including weak ties, statistically significant intervention effects were not observed. Thus, the present study did not conduct post hoc analyses for other variables.

Similar to the main analyses, the path analyses in the sensitivity analyses (Supplemental Figure 2) also revealed that a higher number of intervention participation was statistically significantly associated with increased changes in strong and weak ties and that increased changes in strong ties were associated with those in mental well-being. The correlation coefficients in the path model are shown in Supplemental Table 3. As indicated in Supplemental Table 4, the indirect effect of the number of intervention participation on mental well-being through neighborhood social network was statistically significant, although the total effect of the number of intervention participation on mental well-being was not. Indirect, direct, and total effects on HRQOL and IADL were not statistically significant.

## Discussion

The present study found that participation in our event-based intervention program was indirectly associated with mental well-being mediated by the increase in strong ties among older adults. The indirect effects of the intervention participation on mental well-being were supported in both main and additional sensitivity analyses. The results indicated that the increase in neighborhood social network induced by the intervention prevents decline in mental well-being among older adults. Based on an interventional study design, the present study supports and strengthens the findings of previous observational studies (Litwin, 2011; Li & Zhang, 2015; Santini et al., 2015) on the relations between neighborhood social network

399 and mental health among older adults. For the potential mechanisms of the link between
400 social relationships and health, three potential pathways are generally proposed (Holt-Lunstad
401 & Uchino, 2015; Thoits, 2011; Kawachi et al., 2001): main effect, stress-buffering, and stress-
402 prevention process. The main effect process proposes that sufficient social relationships can
403 provide positive feelings, such as self-esteem and self-control, which can promote health. In
404 stress-buffering process, social relationships weaken the negative influences of stressful
405 events. In stress-prevention process, individuals with sufficient social network have less
406 opportunities to encounter negative life events. In this study, the increase in strong ties with
407 neighbors, along with the potential pathways, may influence one's mental well-being.
408 Additionally, intervention participation would influence mental well-being indirectly
409 and marginally, rather than directly and saliently. In the main analyses, although the path
410 analysis revealed a statistically significant total effect of the intervention participation on
411 mental well-being, the mixed model showed that the statistical significance of the total effect
412 was at threshold level ($p = 0.050$). In the additional sensitivity analyses, both path analysis
413 and mixed model did not support the statistically significant total effect of the number of
414 intervention participation on mental well-being. Similar to the present study, previous review
415 articles (Dickens et al. 2011; Poscia et al., 2018) have shown that the health impacts of
416 interventions targeting social relationships are equivocal. One potential explanation for the
417 unclear total effects of the interventions in both the present and previous studies is that the
418 link between the interventions and mental well-being might not be proximal. Manipulation of
419 social relationships by interventions may not be easy tasks as some previous interventions
420 have failed to improve social relationships (Dickens et al. 2011; Poscia et al., 2018).
421 Moreover, there could be several pathways between social relationships and health status.
422 Regarding the two variables for neighborhood social network, changes in strong ties
423 were favorably associated with those in mental well-being in both main and additional

analyses, whereas changes in weak ties were not statistically significantly associated with those in mental well-being in both analyses. While previous studies for general populations including younger adults have indicated the importance of weak ties for mental health status (Kim, 2019; Sandstrom & Dunn, 2014), it has also been reported that there are age differences in emotional reactions to the social interactions (Birditt, 2014; Charles et al., 2009). The socioemotional selectivity theory (Carstensen, 1999) proposes that as people get older, they prioritize closer social relationships and terminate unimportant relationships, and Lockenhoff and Carstensen (2004) supported this theory. Based on previous studies and findings from the present study, there would be age differences regarding the relative importance of strong and weak ties on mental well-being; strong ties would be more important in the daily lives and mental well-being of older adults. However, further studies would be necessary to confirm the age differences.

In contrary to mental well-being, statistically significant intervention effects on the mental component of HRQOL and statistically significant associations between the mental component of HRQOL and changes in neighborhood social network were not observed. Although mental well-being as measured in the present study reflected the positive aspects of mental health, majority of the items on the mental component of HRQOL measure the negative aspects of mental health. Positive and negative states of mental health are not necessarily on the same dimension (Keyes, 2005). The results implied that neighborhood social network may induce positive feelings rather than reduce negative feelings, thereby corresponding to the main effect process of the potential mechanisms of the link between social relationships and health.

In the present study, the intervention effects on both physical health variables, instrumental activity of daily living, and the physical component of SF-8 were not revealed. Our neighborhood social network intervention would have limited impact on these variables

among older adults. Although the relations between social network and physical health have been mostly confirmed by observational studies, the findings from intervention studies have been ambiguous according to review articles (Dickens et al., 2011; Poscia et al., 2018). Although Dickens et al. (2011) showed that some intervention studies reported statistically significant intervention effects on physical health, Poscia et al. (2018) indicated that recent studies did not report such effects. One potential reason for the inconsistencies is that the link between social relationships and physical health might be more distal than that with mental health. The primary focus of the intervention was improvements of the neighborhood social network and the present study assumes that our program will lead to the improvement of the neighborhood social network mediated by several steps. The present study considers the effects on physical health as just ancillary. Moreover, as Table 1 shows, participants had better physical health status than non-participants, thus, there is not much scope for further improvement of physical health through intervention participation. A low dosage of the intervention would be insufficient to improve physical health and more intensive interventions, such as more frequent and longer-term programs, would be required to impact physical health outcomes.

The strengths of the present study included following three-year-period intervention effects and targeting all older people living in one community. However, the present study had limitations. First, it did not employ the randomized assignments for the intervention or control groups. This would cause self-selection bias. Second, a retrospective self-reported method was used to measure participation in the intervention program. It would cause the recall bias. Moreover, the present study did not measure detailed data for the dosage of the program participation, such as frequencies and intervals of the participation. Such data would be desirable to investigate the effects of the intervention participation more accurately. Third, although the response rate of the baseline survey (61.6%) was comparable to other

474 questionnaire surveys targeting Japanese older population (e.g., 66% in Harada et al., 2017), it
475 might have included selection bias. Fourth, the present study did not consider intervention
476 participation at the neighborhood-level (aggregate level of individual participation) though the
477 social capital studies have indicated the importance of considering it at the neighborhood
478 levels (e.g., Kawachi et al., 1999). Fifth, the path analyses did not examine the time fixed
479 effects. Sixth, the present study did not consider social participation variables at both
480 individual and neighborhood levels, which may serve as important confounders in the
481 analyses. Seventh, there are possibilities of reverse causalities for the link between
482 intervention participation and health status. Therefore, further intervention studies should
483 employ more methodologically sophisticated study designs, such as random assignments,
484 objective measures of participation in the intervention programs, door-to-door surveys,
485 examinations after controlling for neighborhood-level variables and time fixed effects, and
486 careful consideration of reverse causalities. Nonetheless, the present study contributes to
487 better understanding of the associations of neighborhood social network with mental and
488 physical health among older adults.

489 In conclusion, the present study revealed that although desirable influences on the
490 indices of physical health were observed, participation in our event-based intervention
491 indirectly and positively influenced older adults' mental well-being through their strong ties
492 with their neighbors. The findings of the present study strengthen and support previous
493 findings of observational studies on the link between social relationships and mental health.
494 As for the practical implications, our project considered various types of events as
495 intervention programs if the events were attractive to older adults and if the events contained
496 elements facilitating social interaction. If adequate financial support is provided, it would be
497 feasible for many universities to organize event-based community intervention programs. In
498 Japan, a national policy developed by Ministry of Health, Labour and Welfare (2012) called

Healthy Japan 21 set the increase in the number of older adults engaging in social participations as one of its goals of health promotion. Disseminating our intervention program to other universities might contribute to achieving this goal. Further, long-term interventions studies with rigorous study designs and adequate dosages of the program participation would be warranted to confirm the effects of neighborhood social network intervention on health status.

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**Supplemental Materials**

Supplemental Table 1. Correlation coefficients in a path model for associations of intervention participation with neighborhood social network, mental health, and physical health.

Supplemental Table 2. Additional sensitivity analysis for total effects of the number of intervention participation on neighborhood social network, mental health, and physical health: A linear mixed model.

Supplemental Figure 1. Number of intervention participation and changes in social ties. Scores of social ties were adjusted by age, gender, educational background, dummy variables of living arrangements, and working status.

Supplemental Figure 2. Additional sensitivity analysis for path model for associations of the number of intervention participation with neighborhood social network, mental health, and physical health. Bold and dash lines represent statistically significant and non-significant paths, respectively. All path coefficients are standardized. For visual clarity, correlations within demographic factors, between strong and weak ties, and within mental well-being, two components of HRQOL, and IADL are indicated in Supplemental Table 3 and are not displayed in this figure. Dummy variables of living arrangements were removed from the model because all paths from it to number of intervention participation, strong ties, weak ties, mental well-being, HRQOL, and IADL were not statistically significant. Each change score represents residualized change score. GFI = 0.991, AGFI = 0.974, CFI > 0.999, RMSEA < 0.001. *$p$ <0.05, **$p$ <0.01, ***$p$ <0.001. HRQOL: health related quality of life; IADL: instrumental activity of daily living.

Supplemental Table 3. Correlation coefficients in a path model for associations of the number of intervention participation with neighborhood social network, mental health, and physical health.

Supplemental Table 4. Additional sensitivity analysis for direct, indirect, and total effects of the number of intervention participation on neighborhood social network, mental health, and physical health: Path analysis.

Table 1. Participants' Baseline Characteristics. Table 1.

| | Total (N = 662) | | Non-participant (n = 489) | | Participants (n = 173) | | |
|---|---|---|---|---|---|---|---|
| | M or % | SD | M or % | SD | M or % | SD | p-value[a] |
| Demographic factors | | | | | | | |
| Age (years), M | 72.0 | 7.2 | 71.6 | 7.5 | 72.9 | 6.2 | 0.048 |
| Gender (women), % | 56.3% | — | 54.4% | — | 61.6% | — | 0.100 |
| Educational background (> high school), % | 45.6% | — | 42.7% | — | 53.8% | — | 0.012 |
| Living arrangement, % | | | | | | | 0.268 |
| Alone | 20.5% | — | 19.5% | — | 23.3% | — | |
| With spouse | 53.0% | — | 52.5% | — | 54.7% | — | |
| In a multigenerational household | 26.4% | — | 28.0% | — | 22.1% | — | |
| Current working status (yes), % | 26.3% | — | 28.2% | — | 21.1% | — | 0.068 |
| Neighborhood social network | | | | | | | |
| Strong ties (score), M | 2.1 | 2.9 | 1.9 | 2.8 | 2.9 | 2.8 | <0.001 |
| Weak ties (score), M | 11.4 | 9.5 | 10.3 | 8.3 | 14.3 | 11.7 | <0.001 |
| Mental and physical health | | | | | | | |
| Mental well-being (score), M | 30.0 | 6.9 | 29.7 | 7.2 | 30.8 | 6.0 | 0.081 |
| HRQOL mental component (score), M | 50.0 | 6.4 | 49.8 | 6.7 | 50.7 | 5.5 | 0.105 |
| HRQOL physical component (score), M | 47.9 | 6.9 | 47.6 | 7.3 | 49.0 | 5.8 | 0.024 |
| IADL (score), M | 4.8 | 0.6 | 4.8 | 0.7 | 4.9 | 0.3 | 0.009 |

*Note*. *M*: mean; SD: standard deviation; HRQOL: health related quality of life; IADL: instrumental activity of daily living. [a] t-tests for age, strong and weak ties, mental well-being,

HRQOL, and IADL, and chi-squared test for gender, educational background, living arrangement, and current working status.

Table 2. Total Effects of Intervention Participation on Neighborhood Social Network, Mental Health, and Physical Health: A Linear Mixed Model

| | Total *M (SE)* | | Non-participants *M* (*SE*) | | Participants *M* (*SE*) | | Intervention effects, *p*-values[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Group | Time | Group × Time |
| Neighborhood social network | | | | | | | | | |
| Strong ties | 2.1 (0.1) | 2.5 (0.1) | 1.8 (0.2) | 2.0 (0.2) | 2.9 (0.3) | 3.7 (0.3) | 0.001 | 0.104 | 0.031 |
| Weak ties | 11.3 (0.4) | 11.6 (0.4) | 10.2 (0.4) | 10.2 (0.4) | 14.4 (0.7) | 15.4 (0.7) | <0.001 | 0.993 | 0.159 |
| Mental and physical health | | | | | | | | | |
| Mental well-being | 29.9 (0.3) | 29.0 (0.3) | 29.6 (0.3) | 28.4 (0.3) | 30.8 (0.5) | 30.7 (0.5) | 0.039 | <0.001 | 0.050 |
| HRQOL mental component | 50.0 (0.3) | 50.2 (0.3) | 49.7 (0.3) | 49.9 (0.3) | 50.7 (0.5) | 51.0 (0.5) | 0.115 | 0.562 | 0.903 |
| HRQOL physical component | 47.9 (0.3) | 47.2 (0.3) | 47.5 (0.3) | 46.9 (0.3) | 49.2 (0.5) | 48.1 (0.5) | 0.005 | 0.044 | 0.393 |
| IADL | 4.8 (0.0) | 4.7 (0.0) | 4.8 (0.0) | 4.6 (0.0) | 5.0 (0.1) | 4.9 (0.1) | 0.015 | <0.001 | 0.443 |

*Note.* [a] The p-values show the statistical significances of the independent variables in the linear mixed models. In total, six models were examined by setting two neighborhood social network variables and four mental and physical health variables as dependent variables; group (non-participants, participants), time (baseline, follow-up), and the interaction term of group with time as independent variables; and age, gender, educational background, dummy variables of living arrangement, and current working status as covariates. Each model included all data of the

participants without any missing data. *M*: adjusted mean; *SE*: standard error; HRQOL: health related quality of life; IADL: instrumental activity of daily living.

Table 3. Direct, Indirect, and Total Effects of Intervention Participation on Neighborhood Social Network, Mental Health, and Physical Health: Path analysis

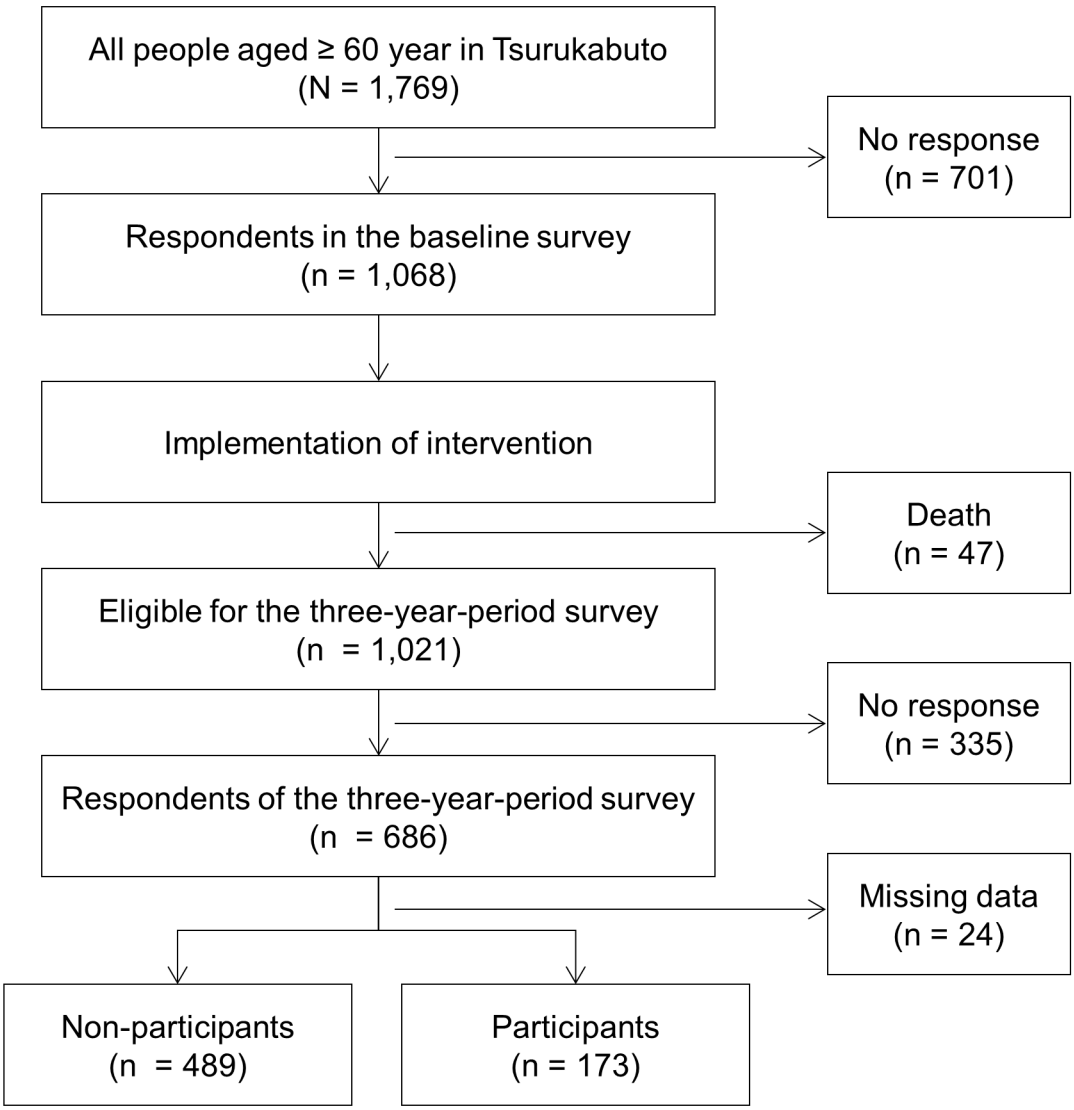
| | Standardized direct effect | | Standardized indirect effect | | Standardized total effect | |
|---|---|---|---|---|---|---|
| | Estimated (95%CI) | *p*-value | Estimated (95%CI) | *p*-value | Estimated (95%CI) | *p*-value |
| Changes in neighborhood social network | | | | | | |
| Changes in strong ties | 0.12 (0.00, 0.21) | 0.045 | — | | 0.12 (0.00, 0.21) | 0.045 |
| Changes in weak ties | 0.21 (0.10, 0.30) | 0.002 | — | | 0.21 (0.10, 0.30) | 0.002 |
| Changes in mental and health status | | | | | | |
| Changes in mental well-being | 0.05 (-0.03, 0.16) | 0.137 | 0.03 (0.01, 0.06) | 0.016 | 0.11 (0.01, 0.20) | 0.028 |
| Changes in HRQOL mental component | 0.05 (-0.05, 0.15) | 0.336 | 0.01 (-0.01, 0.03) | 0.433 | 0.06 (-0.04, 0.16) | 0.236 |
| Changes in HRQOL physical component | -0.03 (-0.12, 0.07) | 0.612 | 0.02 (-0.00, 0.05) | 0.102 | -0.01 (-0.11, 0.09) | 0.853 |
| Changes in IADL | 0.04 (-0.04, 0.12) | 0.225 | 0.02 (-0.00, 0.04) | 0.099 | 0.08 (-0.01, 0.14) | 0.094 |

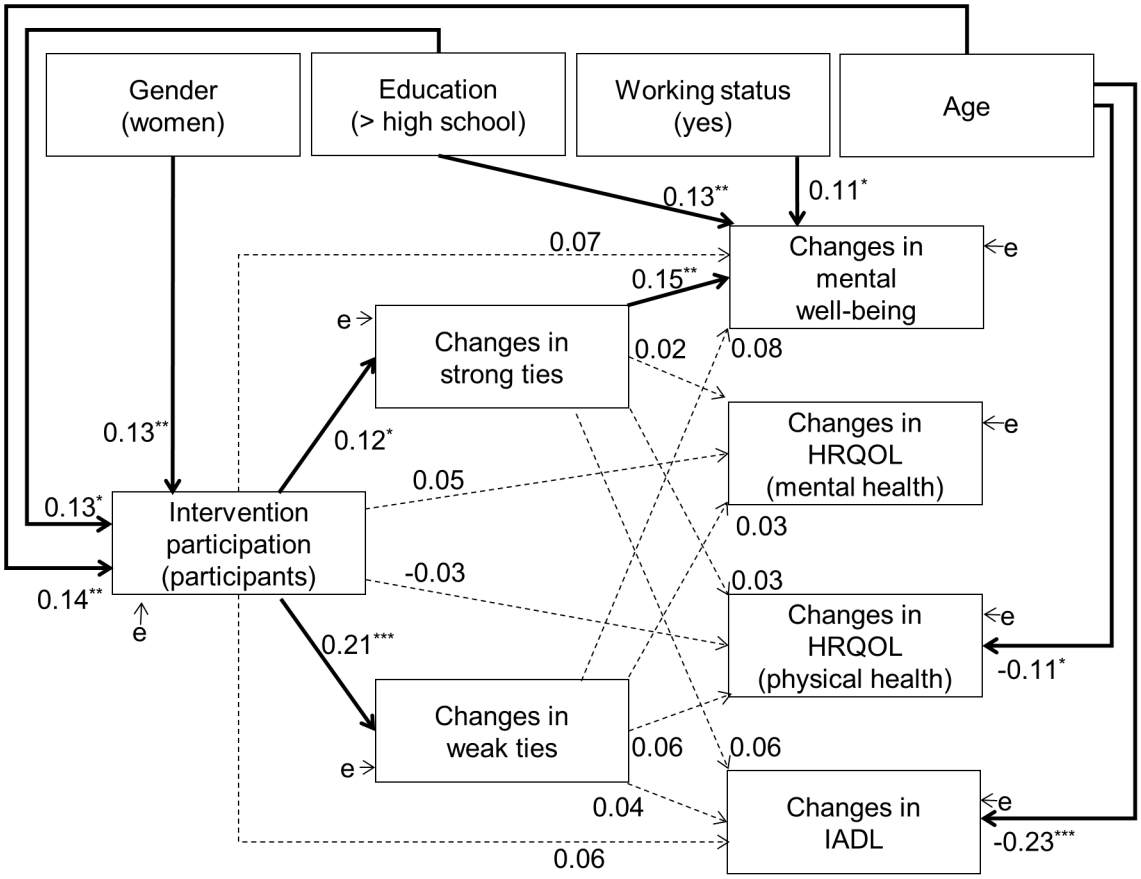
*Note.* The bias-corrected method (1,000 bootstrap samples) was used. 95%CI: 95% confidence interval; HRQOL: health related quality of life; IADL: instrumental activity of daily living. Each change score represents residualized change score. As shown in Figure 2, age, gender, educational background, and current working status were included in the path model.

**Figure Captions**

Figure 1. Flow diagram for examining the three-year-period effects of Tsurukabuto Active Aging Project. This project targeted all older adults living in Tsurulabuto community.

Figure 2. A path model for associations of intervention participation with neighborhood social network, mental health, and physical health. Bold and dash lines represent statistically significant and non-significant paths, respectively. All path coefficients are standardized. For visual clarity, correlations within demographic factors, between strong and weak ties, and within mental well-being, two components of HRQOL, and IADL are indicated in Supplemental Table 1 and not displayed in this figure. Dummy variables of living arrangements were removed from the model because all paths from it to intervention participation, strong ties, weak ties, mental well-being, HRQOL, and IADL were not statistically significant. Each change score represents residualized change score. GFI = 0.990, AGFI = 0.975, CFI > 0.999, RMSEA < 0.001. *p <0.05, **p <0.01, ***p <0.001. HRQOL: health related quality of life; IADL: instrumental activity of daily living.


All people aged ≥ 60 year in Tsurukabuto
(N = 1,769)
No response
(n = 701)
Respondents in the baseline survey
(n = 1,068)
Implementation of intervention
Death
(n = 47)
Eligible for the three-year-period survey
(n = 1,021)
No response
(n = 335)
Respondents of the three-year-period survey
(n = 686)
Missing data
(n = 24)
Non-participants
(n = 489)
Participants
(n = 173)


Gender (women)
Education (> high school)
Working status (yes)
Age
0.13**
0.11*
0.07
Changes in mental well-being
e
0.15**
e
Changes in strong ties
0.02
0.08
0.13**
0.12*
Changes in HRQOL (mental health)
e
0.05
0.13*
Intervention participation (participants)
0.03
-0.03
0.03
0.14**
e
Changes in HRQOL (physical health)
e
0.21***
-0.11*
Changes in weak ties
0.06
0.06
e
0.04
Changes in IADL
e
-0.23***
0.06

Supplementary Table 1. Correlation coefficients in a path model for associations of intervention participation with neighborhood social network, mental health, and physical health.

| | Correlation coefficient | p-value |
|---|---|---|
| Gender and education | -0.19 | <0.001 |
| Gender and working status | -0.21 | <0.001 |
| Age and education | -0.11 | 0.020 |
| Age and working status | -0.42 | <0.001 |
| Changes in strong ties and changes in weak ties | 0.48 | <0.001 |
| Changes in mental well-being and changes in HRQOL (mental health) | 0.34 | <0.001 |
| Changes in mental well-being and changes in HRQOL (physical health) | 0.20 | <0.001 |
| Changes in mental well-being and changes in IADL | 0.25 | <0.001 |
| Changes in HRQOL (mental health) and changes in IADL | 0.12 | 0.015 |
| Changes in HRQOL (physical health) and changes in IADL | 0.13 | 0.011 |

A path model is shown in Figure 2. HRQOL: health related quality of life; IADL: instrumental activity of daily living.

Supplemental Table 2. Additional sensitivity analysis for total effects of the number of intervention participation on neighborhood social network, mental health, and physical health: A linear mixed model.

| | Effects of number of intervention participation[a] | | Effects of time[a] | | Interaction effects[a] | |
|---|---|---|---|---|---|---|
| | B (95%CI) | *p*-values | B (95%CI) | *p*-values | B (95%CI) | *p*-values |
| Neighborhood social network | | | | | | |
| Strong ties | 0.21 (0.07, 0.34) | 0.003 | 0.21 (-0.06, 0.48) | 0.131 | 0.27 (0.15, 0.39) | <0.001 |
| Weak ties | 0.86 (0.50, 1.21) | <0.001 | 0.11 (-0.57, 0.78) | 0.759 | 0.21 (-0.09, 0.51) | 0.160 |
| Mental and physical health | | | | | | |
| Mental well-being | 0.35 (0.08, 0.61) | 0.010 | -0.88 (-1.36, -0.41) | <0.001 | 0.01 (-0.21, 0.22) | 0.951 |
| HRQOL mental component | 0.19 (-0.06, 0.45) | 0.142 | 0.37 (-0.29, 1.02) | 0.273 | -0.13 (-0.43, 0.17) | 0.386 |
| HRQOL physical component | 0.32 (0.06, 0.58) | 0.015 | -0.68 (-1.23, -0.13) | 0.016 | -0.04 (-0.30, 0.21) | 0.749 |
| IADL | 0.03 (-0.00, 0.06) | 0.056 | -0.13 (-0.19, -0.07) | <0.001 | 0.00 (-0.03, 0.03) | 0.883 |

*Note.* [a] Linear mixed models with age, gender, educational background, dummy variables of living arrangement, and current working status as covariates. 95% CI: 95% confidence interval; HRQOL: health related quality of life; IADL: instrumental activity of daily living.

Supplemental Table 3. Additional sensitivity analysis for direct, indirect, and total effects of the number of intervention participation on neighborhood social network, mental health, and physical health: Path analysis

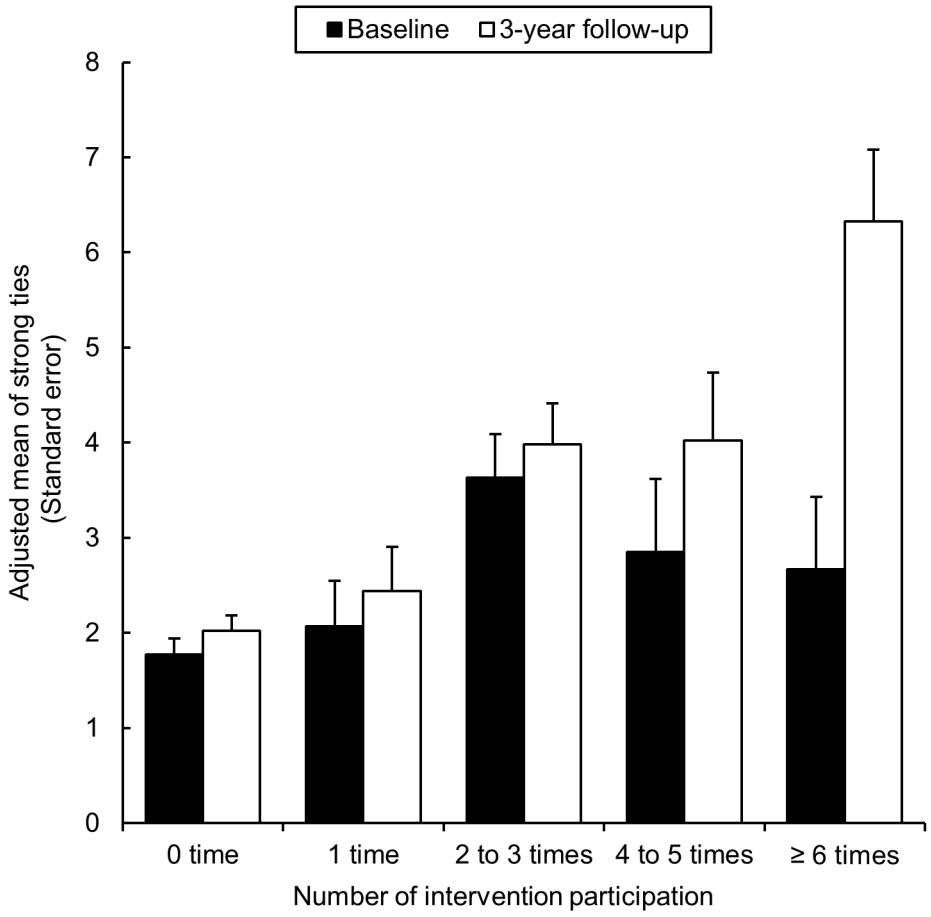
| | Standardized direct effect | | Standardized indirect effect | | Standardized total effect | |
|---|---|---|---|---|---|---|
| | Estimated (95%CI) | *p*-value | Estimated (95%CI) | *p*-value | Estimated (95%CI) | *p*-value |
| Changes in neighborhood social network | | | | | | |
| Changes in strong ties | 0.29 (0.10, 0.45) | 0.002 | — | | 0.29 (0.10, 0.45) | 0.002 |
| Changes in weak ties | 0.20 (0.05, 0.35) | 0.007 | — | | 0.20 (0.05, 0.35) | 0.007 |
| Changes in mental and health status | | | | | | |
| Changes in mental well-being | 0.01 (-0.06, 0.07) | 0.827 | 0.06 (0.01, 0.12) | 0.003 | 0.07 (-0.02, 0.15) | 0.093 |
| Changes in HRQOL MCS | -0.03 (-0.12, 0.06) | 0.539 | 0.02 (-0.01, 0.05) | 0.166 | -0.01 (-0.11, 0.07) | 0.758 |
| Changes in HRQOL PCS | 0.01 (-0.07, 0.08) | 0.814 | 0.01 (-0.02, 0.04) | 0.387 | 0.02 (-0.04, 0.09) | 0.430 |
| Changes in IADL | 0.04 (-0.05, 0.09) | 0.384 | 0.02 (0.00, 0.04) | 0.106 | 0.05 (-0.02, 0.10) | 0.136 |

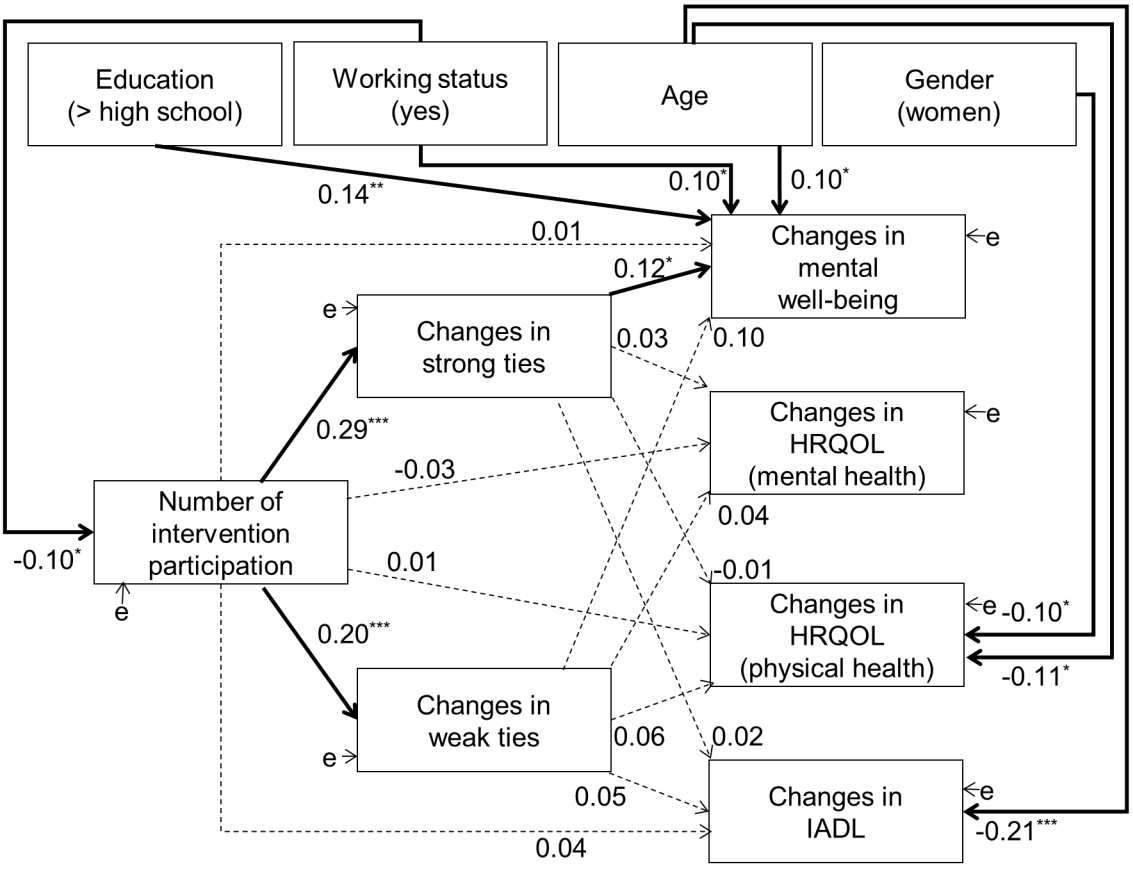
*Note.* The bias-corrected method (1,000 bootstrap samples) was used. 95%CI: 95% confidence interval; HRQOL: health related quality of life; IADL: instrumental activity of daily living. Each change score represents residualized change score. As shown in Supplemental Figure 2, age, gender, educational background, and current working status were included in the path model.

Supplementary Table 4. Correlation coefficients in a path model for associations of the number of intervention participation with neighborhood social network, mental health, and physical health.

| | Correlation coefficient | p-value |
|---|---|---|
| Gender and education | -0.19 | <0.001 |
| Gender and working status | -0.20 | <0.001 |
| Age and education | -0.10 | 0.025 |
| Age and working status | -0.42 | <0.001 |
| Changes in strong ties and changes in weak ties | 0.46 | <0.001 |
| Changes in mental well-being and changes in HRQOL (mental health) | 0.34 | <0.001 |
| Changes in mental well-being and changes in HRQOL (physical health) | 0.16 | <0.001 |
| Changes in mental well-being and changes in IADL | 0.21 | <0.001 |
| Changes in HRQOL (mental health) and changes in IADL | 0.12 | 0.020 |

A path model is shown in Supplemental Figure 2. HRQOL: health related quality of life; IADL: instrumental activity of daily living.


Baseline
3-year follow-up
Adjusted mean of strong ties
(Standard error)
0
1
2
3
4
5
6
7
8
0 time
1 time
2 to 3 times
4 to 5 times
≥ 6 times
Number of intervention participation


Education
(> high school)
Working status
(yes)
Age
Gender
(women)
0.14**
0.10*
0.10*
0.01
Changes in
mental
well-being
e
0.12*
e
Changes in
strong ties
0.03
0.10
0.29***
Changes in
HRQOL
(mental health)
e
-0.03
0.04
Number of
intervention
participation
-0.10*
0.01
-0.01
e
Changes in
HRQOL
(physical health)
e
-0.10*
-0.11*
0.20***
Changes in
weak ties
e
0.06
0.02
0.05
Changes in
IADL
e
-0.21***
0.04