



## Hearing-impaired elderly people have smaller social networks: A population-based aging study

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### ABSTRACT

**Background and objectives:** Hearing impairment (HI) is a major global health concern. In addition, social networks are important for healthy aging. This study aimed to examine the association between HI and social relationships.

**Research design and methods:** This study was conducted by the National Institute for Longevity Sciences as part of its Longitudinal Study of Aging with 1176 Japanese participants aged 60 years or older (mean age  $71.0 \pm 7.4$ ). The convoy model was used to evaluate participants' network size. A pure-tone average hearing level (HL) of 0.5, 1, 2, and 4 kHz in the better ear  $> 25$  dB HL was defined as HI. Multivariate analysis was performed to assess the relationship between HI and the network size, adjusting for age, gender, years of education, presence of depressive symptoms, and higher-level functional capacity score.

**Results:** The mean network sizes across the three circles of the convoy model differed significantly by HI status ( $18.7 \pm 0.4$  in the no-HI group vs  $17.0 \pm 0.5$  in the HI group,  $p = 0.003$ ). In particular, the number of non-kin in the outer circle was significantly less in the HI group ( $4.1 \pm 0.2$  vs  $3.3 \pm 0.3$ ,  $p = 0.004$ ).

**Discussion and implications:** The social network size was significantly smaller in the HI group. The outer circle of people to whom the individual feels less close and the number of non-kin were related to the presence of HI. Therefore, HI may be associated with elderly people's social relationships.

### 1. Introduction

Hearing impairment (HI) is the most common sensory deficit in the human population, and a growing burden of age-related HI has been reported in the most recent Global Burden of Disease Studies (GBD; (Vos et al., 2017; Wilson, Tucci, Merson, & O'Donoghue, 2017). HI became the third-leading cause of years lived with a disability in 2016, although it was the eleventh leading cause of years lived with a disability in the GBD 2010. The results from the GBD 2016 indicate that the number of people with HI is gradually rising, and HI has now become a major concern for global health, especially in the elderly population. However, despite accumulated evidence of its various adverse effects, HI in elderly people remains an invisible disability that is not obvious to others. Therefore, it tends to be ignored, unlike other health

problems.

Social networks and support are important elements for the realization of healthy aging and the well-being of elderly people in aging societies, such as that of Japan. It is widely known that social ties and collaboration have strong relationships with physical and mental health, such as mortality, cognitive dysfunction, well-being, survival after illness, and recovery (Blazer, 1982; Colantonio, Kasl, Ostfeld, & Berkman, 1993; Holtzman et al., 2004; Pinguart & Sorensen, 2000). Social relationships and affiliations are also used as evaluation scales of participation in social activities (Bukov, Maas, & Lampert, 2002), and they represent the structure of interpersonal relationships. However, few studies have examined the association between HI and social relationships.

The convoy model, which is an index of social relations, has been

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widely used since it was proposed by Antonucci et al. in 1980 (Kahn & Antonucci, 1980). According to the convoy model, individuals are surrounded by supportive others who move with them throughout the life course. These relationships vary in their closeness and are influenced by personal (e.g., age) and situational (e.g., national) characteristics and have significant implications for health and well-being (Ajrouch, Fuller, Akiyama, & Antonucci, 2017). A hierarchical mapping procedure using a diagram of concentric circles is used to assess and evaluate social networks and supportive relationships (Antonucci, 1986). This diagram contains three concentric circles with a smaller circle in the center in which the word "you" is written. The ranking of the people that surround the individual at various psychological distances are evaluated.

New findings have continued to be reported in the 40 years that have passed since Kahn and Antonucci developed the convoy model. Tkatch et al. (2011) conducted a survey of 115 African-American patients with an average age of 60.49 years and found that those with larger inner networks had more health support, better health behaviors, and higher coping efficacy (Tkatch et al., 2011). Mejia and Hooker (2014) also reported that the structure and function of elderly people's social convoy contributes to their health and well-being (Mejia & Hooker, 2014). Moreover, Ajrouch et al. (2017) examined national variations in convoy characteristics among older adults across four countries in diverse regions of the world: Japan, Lebanon, Mexico, and the United States. Convoys of social relations include three levels of closeness as indicated by inner, middle, and outer circles that surround the individual. The inner circle often includes immediate family members, whereas the middle and outer circles contain connections beyond immediate family. The aforementioned study found that in Lebanon, Mexico, and the United States, convoy closeness was positively associated with network size: the inner circle was the largest and outer convoy circle the smallest. In Japan, however, network size did not vary by circle closeness; thus, the closest circle was not larger, as was the case in the other nations. The similarities and differences between and among cultures, and the differences of national policies that make formal supports available may be related to the similarities and differences between countries (Ajrouch et al., 2017).

We inferred that adults with HI would be disadvantaged in building social relationships. According to research by Heffernan et al., adults with mild-moderate HI from the UK reported activity limitations and participation restrictions as the most substantial consequences of HI. In particular, adults with HI struggle to communicate with others and have trouble communicating with strangers, since strangers have unfamiliar communication styles and may lack awareness of their interlocutor's hearing loss (Heffernan, Coulson, Henshaw, Barry, & Ferguson, 2016).

Understanding the association between HI and elderly people's social relationships is expected to aid the realization of healthy aging. Therefore, in this study, we examined the association between HI and social relationships in Japanese community-dwellers aged 60 years or older using the convoy model.

## 2. Material and methods

### 2.1. Sample

The data for this survey were collected as part of the National Institute for Longevity Sciences' Longitudinal Study of Aging (NILS-LSA). In this project, the normal aging process was assessed over time using detailed questionnaires and medical checkups, anthropometric measurements such as height and weight, physical fitness tests, and nutritional examinations. Participants in the NILS-LSA include randomly selected age- and sex-stratified individuals from the pool of residents in the National Institute for Longevity Sciences' neighborhood areas of Obu City and Higashiura Town in Aichi Prefecture in Japan. Details of the NILS-LSA study have been reported elsewhere

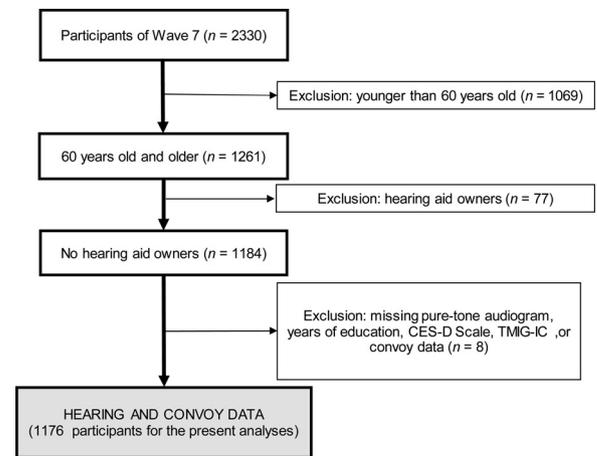


Fig. 1. The participants included in the analyses.

(Shimokata, Ando, & Niino, 2000). The seventh wave of the NILS-LSA was conducted from July 2010 to July 2012.

For the analyses, individuals aged 60 years or older completed an audiometric test and research was conducted using the convoy model. Hearing aid owners were excluded due to deficiencies in the Japanese hearing aid market, in which many internet sales companies sell hearing aids without engaging professional hearing aid technicians to fit customers. It is speculated that using these products may have worse outcomes than using professionally adjusted hearing aids. In the present study, it would be difficult to ascertain whether the participants used good quality products that had been professionally fit from their responses to the questionnaire. Therefore, hearing aid owners were excluded. A total of 1176 people were available for the analyses (Fig. 1).

The NILS-LSA was approved by the Committee of Ethics of Human Research of the National Center for Geriatrics and Gerontology (no. 369-2 and 899-2). Written informed consent was obtained from all participants.

### 2.2. Convoy model

The convoy model is an index of social relations proposed by Antonucci et al. in 1980 (Kahn & Antonucci, 1980). The model ranks the people that surround an individual by their psychological distance. The research was conducted through individual interviews by trained clinical psychologists and psychology graduate students.

After being told that they would be asked about the people they had recently interacted with, the participants were shown a diagram that contained three concentric circles with a smaller circle in the center in which the word "you" was written. The participants were asked about the range of their relationships with others and to write the names of the relationships in each circle. First, participants were asked to fill in the inner circle by naming the people with whom they had a stable and intimate relationship for a long time and without whom they could not imagine life (spouses, lovers, and best friends are typical examples). Second, the same procedure was followed in the middle circle for people to whom they may not feel quite so close but who were still important to them. These people are close but can easily change over time (for example, relatives who do not live with them and friends). Finally, in the outer circle, they were asked to name the people that they had not already mentioned but who were close enough and important enough in their lives that they should be placed in the personal network. These members are people with whom there is a significant but usually singular relationship. These relationships tend to be very role-prescribed, and they can change as one's social position changes (for example, co-workers and family doctors). In other words, the closer one is to the participant's inner circle, the more intimate their relationship with the participant.

The number of people with whom participants had interpersonal relationships, but not intergroup relationships, was counted for the present analyses with the type based on whether they were kin. The number of people included in each circle or the sum of the number of network members nominated by the participants across the three circles (inner, middle, and outer) were used as indicators in the analyses.

### 2.3. Audiometric test and demographic questionnaires

Air-conduction pure-tone thresholds at octave intervals from 0.125 kHz to 8 kHz were measured in a sound-proof booth by trained medical technicians using a standardized protocol and a diagnostic audiometer (AA-78; Rion, Tokyo, Japan). The pure-tone average threshold level of the better ear at frequencies of 0.5, 1, 2, and 4 kHz was used as an index of hearing status. HI was defined as greater than 25 dB hearing level (HL) according to the World Health Organization's grades (WHO, 2018).

Participants completed a series of questionnaires in advance of the examination. Data on participants' years of education were collected using self-report questionnaires. Additionally, as potential confounders that might be related to social relationships, depressive symptoms and higher-level functional capacity were assessed. The Center for Epidemiologic Studies Depression Scale (Radloff, 1977) was used for the evaluation of depressive symptoms. Scores on this scale range from 0 to 60; a score of 16 or higher is defined as depression. Participants' scores on the Tokyo Metropolitan Institute of Gerontology's Index of Competence were used to evaluate their higher-level functional capacity. This index was designed to measure higher-level functional capacity above the basic activities of daily living (ADL) based on Lawton's hierarchical model of competence specifically for Japanese older adults. It consists of three subscales: instrumental self-maintenance, intellectual activity, and social role (Koyano, Shibata, Nakazato, Haga, & Suyama, 1991; Lawton & Brody, 1969). It is a multidimensional 13-item index. The response to each item is scored with either 1 (yes) or 0 (no), and a higher score reflects higher-level functional capacity.

### 2.4. Statistical analyses

The statistical analyses were conducted using the Statistical Analysis System (SAS) software version 9.3 (SAS Institute, Cary, NC, USA). For the univariate analysis, the participants' characteristics were compared in terms of having HI or not using *t*-tests for continuous variables and  $\chi^2$ -tests for categorical variables.

In the multivariate analysis, the general linear model procedure was performed to analyze the association of HI with the network size obtained by the convoy model. The number of people who were included in each circle or the sum of people in the convoy model were used as the dependent variables. The presence or absence of HI was used as the independent variable. Age, gender, years of education, presence of depressive symptoms, and higher-level functional capacity score were used as the dummy variables. *P*-values < 0.05 were considered significant.

## 3. Results

The characteristics of the surveyed participants are shown in Table 1. Between the two groups classified by hearing status (i.e., no-HI and HI), significant differences were found in the mean age, proportion of males, years of education, presence of depressive symptoms, and score of higher-level functional capacity.

The results of the multivariate analyses are presented in Tables 2–4. When the number of people in each circle was compared between the no-HI and HI groups considering the confounding factors, a significant difference was observed in the outer circle. The number of people included in the outer circle was significantly less in the HI group than in the no-HI group (no-HI vs HI;  $4.6 \pm 0.2$  vs  $3.7 \pm 0.3$ ,  $p = 0.001$ ),

whereas there was no difference in the inner and middle circles (inner circle:  $7.3 \pm 0.2$  vs  $7.1 \pm 0.2$ ,  $p = 0.430$ , middle circle:  $6.7 \pm 0.2$  vs  $6.2 \pm 0.3$ ,  $p = 0.156$ ; Table 2).

The number of kin did not significantly differ between the no-HI and HI groups in each circle (Table 3). There was no difference in the number of non-kin included in the inner and middle circles (inner circle:  $0.7 \pm 0.1$  vs  $0.6 \pm 0.1$ ,  $p = 0.409$ , middle circle:  $3.2 \pm 0.2$  vs  $2.9 \pm 0.2$ ,  $p = 0.365$ ), although the number of non-kin included in the outer circle was significantly less in the HI group ( $4.1 \pm 0.2$  vs  $3.3 \pm 0.3$ ,  $p = 0.004$ ; Table 3).

The mean network size obtained as the sum of the number of network members across the three circles was  $18.7 \pm 0.4$  in the no-HI group and  $17.0 \pm 0.5$  in the HI group, and there was a significant difference between the two groups ( $p = 0.003$ ). The total number of kin belonging to the three circles did not significantly differ between the no-HI and HI groups ( $10.7 \pm 0.3$  vs  $10.2 \pm 0.3$ ,  $p = 0.164$ ). The total number of non-kin belonging to the three circles in the HI group was significantly less than in the no-HI group ( $8.0 \pm 0.3$  vs  $6.8 \pm 0.4$ ,  $p = 0.005$ ; Table 4).

## 4. Discussion and implications

The current study explored whether social network size indicated by the convoy model has an association with the presence or absence of HI in Japanese community-dwellers aged 60 years or older. The main finding was that the social network size, expressed as the sum of the number of network members, was significantly smaller in the group with HI than in the group without HI, even after adjusting for potential confounders. The existence of HI can be related to the social relationships of elderly people.

The social networks of elderly people have been reported to be affected by various factors such as their age, sex, educational background, ADL, and mental health (Brown & Ferris, 2007; De Leon et al., 1999; Koizumi et al., 2005). Even when taking these effects into consideration, the association of HI with social network size remained significant in the current analyses.

Network size is one of the most important characteristics of social relationships; it is an indicator of one's degree of socializing and potential instrumental and emotional support (Van Tilburg, 1995). Social network sizes affect elderly people's mental and general health, such as their mortality, cognitive dysfunction, onset of heart disease, and onset of stroke and delay in recovery from it (Awata et al., 2005; Blazer, 1982; Colantonio et al., 1993; Holtzman et al., 2004; Orth-Gomer, Rosengren, & Wilhelmsen, 1993).

In this study, regarding the psychological distance, we observed that in the inner circle, the network size of people with whom the individual had intimate relationships did not differ according to the presence of HI. However, the outer circle, which contains people whom the individual feels less close to and has only social relationships with, was associated with the presence of HI.

HI individuals were more likely to report fewer non-kin members and to name fewer in the outer circle of the convoy model than the no-HI individuals. As a result, the total number of people in the whole circle was smaller, indicating that the network size was smaller. This finding suggests that HI is associated with the network structure of elderly people. To keep the network size larger, it is important to retain or increase the number of non-kin because the number of kin cannot be modified. HI can disturb elderly people's communication, which can affect their social networks, and may indirectly affect their general and mental health.

A growing number of studies have demonstrated the substantial impact of rich social networks on health and survival (Ellwardt, van Tilburg, Aartsen, Wittek, & Steverink, 2015; Holt-Lunstad, Smith, & Layton, 2010; Smith & Christakis, 2008). Large and diverse personal networks reduce the risk of common diseases and adverse events in elderly adults through a variety of mechanisms, including the provision

**Table 1**  
Characteristics of the Surveyed Participants.

	Total N = 1176	No hearing impairment N = 766	Hearing impairment N = 410	p-value
Mean age, years	71.0 ± 7.4	68.5 ± 6.3	75.6 ± 6.9	< 0.001
Sex, male (%)	50.6	48.8	53.9	0.097
Years of education, years	11.8 ± 2.6	12.1 ± 2.5	11.1 ± 2.6	< 0.001
Presence of depressive symptoms (%)	13.0	10.6	17.6	< 0.001
Score of TMIG-IC, (points)	12.1 ± 1.4	12.2 ± 1.4	11.8 ± 1.4	< 0.001

Notes: Values are expressed as means ± standard deviation; TMIG-IC = Tokyo Metropolitan Institute of Gerontology Index of Competence.

Hearing impairment is defined as pure tone average > 25 dB HL at 0.5–4 kHz in the better ear.

P-values for continuous variables based on t-test, for dichotomous variables based on Chi-squared test.

**Table 2**  
The Number of People in Each Circle.

N = 1176	No hearing impairment N = 766	Hearing impairment N = 410	p-value
The inner circle	7.3 ± 0.2	7.1 ± 0.2	0.430
The middle circle	6.7 ± 0.2	6.2 ± 0.3	0.156
The outer circle	4.6 ± 0.2	3.7 ± 0.3	0.001

Notes: Values are expressed as means ± standard error. Multivariate analysis using a general linear model procedure was performed with adjustment for age, gender, years of education, presence of depressive symptoms, and score of Tokyo Metropolitan Institute of Gerontology Index of Competence.

**Table 3**  
The Number of Kin or Non-Kin in Each Circle.

N = 1176	No hearing impairment N = 766	Hearing impairment N = 410	p-value
The number of kin in the inner circle	6.6 ± 0.2	6.5 ± 0.2	0.627
in the middle circle	3.5 ± 0.2	3.3 ± 0.2	0.335
in the outer circle	0.5 ± 0.1	0.4 ± 0.1	0.139
The number of non-kin in the inner circle	0.7 ± 0.1	0.6 ± 0.1	0.409
in the middle circle	3.2 ± 0.2	2.9 ± 0.2	0.365
in the outer circle	4.1 ± 0.2	3.3 ± 0.3	0.004

Notes: Values are expressed as means ± standard error. Multivariate analysis using a general linear model procedure was performed with adjustment for age, gender, years of education, presence of depressive symptoms, and score of Tokyo Metropolitan Institute of Gerontology Index of Competence.

**Table 4**  
The Number of Kin or Non-Kin in All Circles.

N = 1176	No hearing impairment N = 766	Hearing impairment N = 410	p-value
Kin	10.7 ± 0.3	10.2 ± 0.3	0.164
Non-kin	8.0 ± 0.3	6.8 ± 0.4	0.005
Total number	18.7 ± 0.4	17.0 ± 0.5	0.003

Notes: Values are expressed as means ± standard error. Multivariate analysis using a general linear model procedure was performed with adjustment for age, gender, years of education, presence of depressive symptoms, and score of Tokyo Metropolitan Institute of Gerontology Index of Competence.

of social support and social influence concerning psychological and physiological health benefits.

In this study, it was found that HI is associated with the outer circle, especially non-kin. This may be related to communication difficulties and subsequently decreased social participation. Heffernan et al. reported that people with HI often find it difficult to communicate with people who are unfamiliar, especially people with unfamiliar voices and accents. They may also lack the confidence to approach new people and build new relationships due to the stigma associated with HI and

out of fear of communication difficulties (Heffernan et al., 2016). On the other hand, even close family members of people with HI, such as their spouses, often find it difficult to communicate with people with HI (Barker, Leighton, & Ferguson, 2017). It may be even more difficult for non-kin in the outer circle who may have little awareness of how to communicate with people who have HI. Individuals with HI could tend to withdraw from situations in which they may have difficulty hearing and communicating. Such behavior may be a reason for their small personal networks.

Many epidemiologic studies have demonstrated that HI is associated with various adverse effects, such as social isolation (Dawes et al., 2015; Mick & Pichora-Fuller, 2016; Mick, Kawachi, & Lin, 2014), loneliness (Sung, Li, Blake, Betz, & Lin, 2016), depression (Pronk, Deeg, & Kramer, 2013), lower cognitive functioning (Loughrey, Kelly, Kelley, Brennan, & Lawlor, 2018), frailty (Liljas et al., 2016), falls (Grue, Kirkevold, Mowinchel, & Ranhoff, 2008), stigma (Barker et al., 2017), and poor ADL (Gopinath et al., 2012; Yamada, Nishiwaki, Michikawa, & Takebayashi, 2012).

Of these, Mick et al. (2014) reported that greater hearing loss was associated with increased odds of being socially isolated in a nationally representative sample of women aged 60–69 years. In addition, participants with pure-tone average > 25 dB HL who self-reported their hearing ability to be “good” or “excellent” were associated with increased risk of social isolation and lower cognitive scores (Mick & Pichora-Fuller, 2016). Furthermore, Sung et al. (2016) demonstrated that younger age and greater hearing loss are independently associated with higher levels of loneliness in older adults. The current study suggested that social network size is smaller in hearing-impaired individuals, which may lead to social isolation or loneliness in elderly people.

In this study, we focused on the quantity rather than the quality of one’s social relationships. The network size of the inner and middle circles and the number of kin in each circle were not significantly related to participants’ hearing status. However, the quality of the relationships might be different by HI status even in stable and intimate relationships.

Heffernan et al. reported that people with HI sometimes physically present a passive rather than an active presence in social situations because they have difficulty following the conversation (Heffernan et al., 2016). This suggests that although people with HI are present at social gatherings, they withdraw from social interactions due to communication problems.

Pinquart et al. reported that the quantity of social contact was not as highly correlated with subjective well-being, considered an aspect of successful aging, as the quality of contact (Pinquart & Sorensen, 2000). Coyle et al. reported that loneliness is associated with higher odds of having a mental health problem, and isolation is associated with higher odds of reporting one’s health as being fair or poor (Coyle & Dugan, 2012).

From the existing data, in order to address the quality of the social relationships of the present subjects, we picked out some queries available in the NILS-LSA database and performed sub-analyses. Some

of the questionnaires in the NILS-LSA database asked the elderly participants about emotional support. For example, “Is there anyone who listen to your worries and troubles?” “Is there anyone who pay attention to you?” “Is there anyone who cheer you up?” and “Is there anyone who makes you feel relaxed?” These original questions are used with reference to the questionnaire about social support for elderly people produced by [Noguchi \(1991\)](#). Each question was scored as 1 (“there is none”), 2 (“there are few”), 3 (“there are a few”), and 4 (“there are some”). These questions referred to support from non-family members, respectively. We compared the scores for each question in the HI group and the no-HI group. Multivariate analysis was performed adjusting for the same confounders as the main analyses, and people with HI had a lower score of non-family support for the question “Is there anyone who listen to your worries and troubles?” ( $2.9 \pm 0.04$  points in the no-HI group vs  $2.8 \pm 0.04$  points in the HI group,  $p < 0.05$ ). The scores of the other three questions about non-family support and the scores of every question about family support had no significant difference.

The results from this sub-analysis using existing data were insufficient to verify a difference by HI status in the quality of social relationships. Further detailed investigation is necessary to clarify the impact of HI on the quality of one’s social relationships.

We acknowledge that this study has some limitations. First, the results of the present cross-sectional analyses are not sufficient for debating whether a cause-and-effect relationship exists between HI and social network size. The present analytical cross-sectional studies are useful for establishing preliminary evidence for a link between the two, but interpretation requires caution regarding the potential association. Further analyses by longitudinal design are required.

Second, unmeasured confounds or insufficient control of measured confounds might explain the association between HI and social networks. It has been reported that HI is linked to comorbidity of a wide range of chronic health conditions such as diabetes, cardiovascular disease, and dementia ([Gates, Cobb, D’Agostino, & Wolf, 1993](#); [Horikawa et al., 2013](#); [Uhlmann, Larson, Rees, Koepsell, & Duckert, 1989](#)). People with HI may have smaller social networks because of participation restrictions from comorbid health conditions rather than HI. Although seriously mentally or physically impaired individuals did not participate, higher-level functional capacity was used for adjustment in the present analyses because limited ADL affects social integration ([Drageset, 2004](#); [Tanaka & Johnson, 2010](#)).

Third, there is a potential selection bias, as the participants of this study were a stratified random sample of community-dwelling elderly people; however, they were relatively healthy elderly people who could travel to participate in the study at our institution. It was not possible to reflect the actual situation of the aged population, including individuals who need nursing care or are hospitalized.

There is a potential selection bias regarding HI. WHO has set HI  $> 40$  dB HL as the disabling hearing loss level ([WHO, 2018](#)). In this study, there were not many people with moderate or severe HI, and the number of people with HI  $> 40$  dB HL was 77 (6.5%). The participants of the NILS-LSA may generally be healthier than the rest of the elderly population, and particularly healthier than those in outpatient surveys. Further research conducted with people with more severe HI and those seeking help with their hearing is required.

The advantage of using an audiometric measurement of hearing is that the extent of participants’ HI was evaluated more accurately than by subjective assessments of hearing difficulty such as questionnaires. Self-reported assessments of hearing are frequently utilized in large-scale research studies to reduce demands on the facility, equipment, technicians, and time. However, inconsistencies between subjective and audiometric assessments have been identified, especially in the elderly population ([Kamil, Genther, & Lin, 2015](#)). We previously reported that elderly participants underestimate their hearing difficulty in comparison with middle-aged participants ([Uchida, Nakashima, Ando, Niino, & Shimokata, 2003](#)).

Since we evaluated the extent of participants’ HI using pure-tone

thresholds, individuals with HI greater than 25 dB HL were detected regardless of severity. Interventions for HI, such as the usage of hearing aids or cochlear implants, may make it possible for people with HI to resume participation in personal networks. In the present study, hearing aid owners were excluded because of unascertained usage conditions and fitting. Further study is needed of whether interventions for HI can improve the social networks of elderly people with HI in order to optimally position hearing loss among other aging health-care priorities. In another ongoing project, we are conducting a 6-month follow-up study on help-seeking outpatients with hearing impairment. The goal is to assess the effect of hearing aids on executive function and social interaction by comparing participants before and after hearing aid introduction. We aim to understand the effect of HI on social networks with appropriate hearing aid intervention by medical professionals.

## 5. Conclusions

In this study, we examined the association between HI and the social relationships of elderly people. We found that in the HI group, the number of non-kin members was mainly lower in the outer circle, and as a result, the total number of people in the entire circle was smaller, which means that the network size was smaller. We conclude that HI is one of the dominant factors related to the social relationships of elderly people.

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## Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## References

- Ajrouch, K. J., Fuller, H. R., Akiyama, H., & Antonucci, T. C. (2017). Convoys of social relations in cross-national context. *Gerontologist*. <https://doi.org/10.1093/geront/gnw204>.
- Antonucci, T. C. (1986). Social support networks: Hierarchical mapping technique. *Generations*, 10(4), 10–12.
- Awata, S., Seki, T., Koizumi, Y., Sato, S., Hozawa, A., Omori, K., ... Tsuji, I. (2005). Factors associated with suicidal ideation in an elderly urban Japanese population: A community-based, cross-sectional study. *Psychiatry and Clinical Neurosciences*, 59(3), 327–336. <https://doi.org/10.1111/j.1440-1819.2005.01378.x>.
- Barker, A. B., Leighton, P., & Ferguson, M. A. (2017). Coping together with hearing loss: A qualitative meta-synthesis of the psychosocial experiences of people with hearing loss and their communication partners. *International Journal of Audiology*, 56(5), 297–305. <https://doi.org/10.1080/14992027.2017.1286695>.
- Blazer, D. G. (1982). Social support and mortality in an elderly community population. *American Journal of Epidemiology*, 115(5), 684–694.
- Brown, E., & Ferris, J. M. (2007). Social capital and philanthropy: An analysis of the impact of social capital on individual giving and volunteering. *Nonprofit and Voluntary Sector Quarterly*, 36(1), 85–99. <https://doi.org/10.1177/0899764006293178>.

- Bukow, A., Maas, I., & Lampert, T. (2002). Social participation in very old age: Cross-sectional and longitudinal findings from base. Berlin aging study. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 57(6), P510–517.
- Colantonio, A., Kasl, S. V., Ostfeld, A. M., & Berkman, L. F. (1993). Psychosocial predictors of stroke outcomes in an elderly population. *Journal of Gerontology*, 48(5), S261–268.
- Coyle, C. E., & Dugan, E. (2012). Social isolation, loneliness and health among older adults. *Journal of Aging and Health*, 24(8), 1346–1363. <https://doi.org/10.1177/0898264312460275>.
- Dawes, P., Emsley, R., Cruickshanks, K. J., Moore, D. R., Fortnum, H., Edmondson-Jones, M., ... Munro, K. J. (2015). Hearing loss and cognition: The role of hearing aids, social isolation and depression. *PLoS One*, 10(3), e0119616. <https://doi.org/10.1371/journal.pone.0119616>.
- De Leon, C. F. M., Glass, T. A., Beckett, L. A., Seeman, T. E., Evans, D. A., & Berkman, L. F. (1999). Social networks and disability transitions across eight intervals of yearly data in the new haven epe. *The Journals of Gerontology Series B*, 54(3), S162–S172.
- Drageset, J. (2004). The importance of activities of daily living and social contact for loneliness: A survey among residents in nursing homes. *Scandinavian Journal of Caring Sciences*, 18(1), 65–71.
- Ellwardt, L., van Tilburg, T., Aartsen, M., Wittek, R., & Steverink, N. (2015). Personal networks and mortality risk in older adults: A twenty-year longitudinal study. *PLoS One*, 10(3), e0116731. <https://doi.org/10.1371/journal.pone.0116731>.
- Gates, G. A., Cobb, J. L., D'Agostino, R. B., & Wolf, P. A. (1993). The relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors. *Archives of Otolaryngology—Head & Neck Surgery*, 119(2), 156–161.
- Gopinath, B., Schneider, J., McMahon, C. M., Teber, E., Leeder, S. R., & Mitchell, P. (2012). Severity of age-related hearing loss is associated with impaired activities of daily living. *Age and Ageing*, 41(2), 195–200. <https://doi.org/10.1093/ageing/af1155>.
- Grue, E. V., Kirkevold, M., Mowinchel, P., & Ranhoff, A. H. (2008). Sensory impairment in hip-fracture patients 65 years or older and effects of hearing/vision interventions on fall frequency. *Journal of Multidisciplinary Healthcare*, 2, 1–11.
- Heffernan, E., Coulson, N. S., Henshaw, H., Barry, J. G., & Ferguson, M. A. (2016). Understanding the psychosocial experiences of adults with mild-moderate hearing loss: An application of leventhal's self-regulatory model. *International Journal of Audiology*, 55(Suppl. 3), S3–S12. <https://doi.org/10.3109/14992027.2015.1117663>.
- Holt-Lunstad, J., Smith, T. B., & Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*, 7(7), e1000316. <https://doi.org/10.1371/journal.pmed.1000316>.
- Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 59(6), P278–284.
- Horikawa, C., Kodama, S., Tanaka, S., Fujihara, K., Hirasawa, R., Yachi, Y., ... Sone, H. (2013). Diabetes and risk of hearing impairment in adults: A meta-analysis. *The Journal of Clinical Endocrinology and Metabolism*, 98(1), 51–58. <https://doi.org/10.1210/jc.2012-2119>.
- Kahn, R. L., & Antonucci, T. C. (1980). Convoys over the life course: Attachment, roles, and social support. In P. B. Baltes, & O. G. Brim (Eds.). *Life-span development and behavior* (pp. 253–286). New York: Academic Press.
- Kamil, R. J., Genther, D. J., & Lin, F. R. (2015). Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear and Hearing*, 36(1), 164–167.
- Koizumi, Y., Awata, S., Kuriyama, S., Ohmori, K., Hozawa, A., Seki, T., ... Tsuji, I. (2005). Association between social support and depression status in the elderly: Results of a 1-year community-based prospective cohort study in Japan. *Psychiatry and Clinical Neurosciences*, 59(5), 563–569. <https://doi.org/10.1111/j.1440-1819.2005.01415.x>.
- Koyano, W., Shibata, H., Nakazato, K., Haga, H., & Suyama, Y. (1991). Measurement of competence: Reliability and validity of the tmig index of competence. *Archives of Gerontology and Geriatrics*, 13(2), 103–116.
- Lawton, M. P., & Brody, E. M. (1969). Assessment of older people: Self-maintaining and instrumental activities of daily living. *Gerontologist*, 9(3), 179–186.
- Liljas, A., Carvalho, L. A., Papachristou, E., Ramsay, S. E., Wannamethee, G., De Oliveira, C., & Walters, K. (2016). Hearing impairment and frailty in English community-dwelling older adults: A 4-year follow-up study. *Gerontologist*, 56, 319.
- Loughrey, D. G., Kelly, M. E., Kelley, G. A., Brennan, S., & Lawlor, B. A. (2018). Association of age-related hearing loss with cognitive function, cognitive impairment, and dementia: A systematic review and meta-analysis (vol 144, pg 115, 2018). *JAMA Otolaryngology—Head & Neck Surgery*, 144(2), 176.
- Mejia, S. T., & Hooker, K. (2014). Relationship processes within the social convoy: Structure, function, and social goals. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 69(3), 376–386. <https://doi.org/10.1093/geronb/gbt011>.
- Mick, P., & Pichora-Fuller, M. K. (2016). Is hearing loss associated with poorer health in older adults who might benefit from hearing screening? *Ear and Hearing*, 37(3), e194–201. <https://doi.org/10.1097/aud.0000000000000267>.
- Mick, P., Kawachi, I., & Lin, F. R. (2014). The association between hearing loss and social isolation in older adults. *Otolaryngology—Head and Neck Surgery*, 150(3), 378–384. <https://doi.org/10.1177/0194599813518021>.
- Noguchi, Y. (1991). Social support for elderly people—Its concept and measurement. *Social Gerontology, Tokyo: The Tokyo Metropolitan Institute of Gerontology*, 34, 37–48 (In Japanese).
- Orth-Gomer, K., Rosengren, A., & Wilhelmsen, L. (1993). Lack of social support and incidence of coronary heart disease in middle-aged Swedish men. *Psychosomatic Medicine*, 55(1), 37–43.
- Pinquart, M., & Sorensen, S. (2000). Influences of socioeconomic status, social network, and competence on subjective well-being in later life: A meta-analysis. *Psychology and Aging*, 15(2), 187–224.
- Pronk, M., Deeg, D. J., & Kramer, S. E. (2013). Hearing status in older persons: A significant determinant of depression and loneliness? Results from the longitudinal aging study Amsterdam. *American Journal of Audiology*, 22(2), 316–320. [https://doi.org/10.1044/1059-0889\(2013\)12-00699](https://doi.org/10.1044/1059-0889(2013)12-00699).
- Radloff, L. S. (1977). The CES-D Scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, 1, 385–401.
- Shimokata, H., Ando, F., & Niino, N. (2000). A new comprehensive study on aging the National Institute for Longevity Sciences, Longitudinal Study of Aging (NILS-LSA). *Journal of Epidemiology*, 10(Suppl. 1), 1–9. <https://doi.org/10.2188/jea.10.1sup.1>.
- Smith, K. P., & Christakis, N. A. (2008). Social networks and health. *Annual Review of Sociology*, 34, 405–429. <https://doi.org/10.1146/annurev.soc.34.040507.134601>.
- Sung, Y. K., Li, L., Blake, C., Betz, J., & Lin, F. R. (2016). Association of hearing loss and loneliness in older adults. *Journal of Aging and Health*, 28(6), 979–994. <https://doi.org/10.1177/0898264315614570>.
- Tanaka, K., & Johnson, N. E. (2010). Social integration and healthy aging in Japan: How gender and rurality matter. *Journal of Cross-Cultural Gerontology*, 25(2), 199–216. <https://doi.org/10.1007/s10823-010-9118-6>.
- Tkatch, R., Artinian, N. T., Abrams, J., Mahn, J. R., Franks, M. M., Keteyian, S. J., ... Schwartz, S. (2011). Social network and health outcomes among african american cardiac rehabilitation patients. *Heart Lung*, 40(3), 193–200. <https://doi.org/10.1016/j.hrtlng.2010.05.049>.
- Uchida, Y., Nakashima, T., Ando, F., Niino, N., & Shimokata, H. (2003). Prevalence of self-perceived auditory problems and their relation to audiometric thresholds in a middle-aged to elderly population. *Acta Oto-Laryngologica*, 123(5), 618–626. <https://doi.org/10.1080/00016480310001448>.
- Uhlmann, R. F., Larson, E. B., Rees, T. S., Koepsell, T. D., & Duckert, L. G. (1989). Relationship of hearing impairment to dementia and cognitive dysfunction in older adults. *JAMA*, 261(13), 1916–1919.
- Van Tilburg, T. G. (1995). *Delineation of the social network and differences in network size. Living arrangements and social networks of older adults*83–96.
- Vos, T., Abajobir, A. A., Abate, K. H., Abbafati, C., Abbas, K. M., Abd-Allah, F., ... Murray, C. J. L. (2017). Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: A systematic analysis for the global burden of disease study 2016. *The Lancet*, 390(10100), 1211–1259. [https://doi.org/10.1016/s0140-6736\(17\)32154-2](https://doi.org/10.1016/s0140-6736(17)32154-2).
- WHO (2018). *Grades of hearing impairment*. (Accessed 15 December 2018) [https://www.who.int/pbd/deafness/hearing\\_impairment\\_grades/en/](https://www.who.int/pbd/deafness/hearing_impairment_grades/en/).
- Wilson, B. S., Tucci, D. L., Merson, M. H., & O'Donoghue, G. M. (2017). Global hearing health care: New findings and perspectives. *The Lancet*, 390(10111), 2503–2515. [https://doi.org/10.1016/s0140-6736\(17\)31073-5](https://doi.org/10.1016/s0140-6736(17)31073-5).
- Yamada, M., Nishiwaki, Y., Michikawa, T., & Takebayashi, T. (2012). Self-reported hearing loss in older adults is associated with future decline in instrumental activities of daily living but not in social participation. *Journal of the American Geriatrics Society*, 60(7), 1304–1309. <https://doi.org/10.1111/j.1532-5415.2012.04039.x>.