**Title:** Associations between driving status, frequency of transport use after driving cessation, and social frailty among middle-aged and older people aged 60 years and older

**Running title:** Transport use and social frailty

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Informed consent: All Participants included in this study provided their written consent to participate in the study.
Title: Associations between driving status, frequency of transport use after driving cessation, and social frailty among middle-aged and older people aged 60 years and above

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Abstract

Background: The use of transport other than cars is a modifiable factor in the association between driving cessation and social frailty. Clarifying this relationship may serve as a new preventive measure against social frailty among current non-drivers. This study examined the potential association of driving status and transport use with social frailty, as well as between the frequency of transport use and social frailty, among current non-drivers.

Methods: This study included 977 middle-aged and older adults (average age 65.3 ± 4.8 years). The participants were classified as transport users (more than a few times a week) and transport non-users (less than a few times a month). Based on driving status and transport use, the groups were further classified into current driver, current non-driver/transport user, and current non-driver/transport non-user groups. We performed statistical analyses to examine the relationships between driving status, transport use, and social frailty.

Results: The current non-driver/transport non-user group showed a significant association with a higher social frailty. The current non-driver/transport user group showed no association with social frailty compared with the current driver group. The current non-driver/transport non-user group showed a significant association with a higher social frailty rate (OR 2.14, 95%CI 1.25–3.73).

Conclusions: Participants who did not drive or take transport showed significant associations with increased social frailty. Compared with current driver/transport use, current non-driver/transport non-use was associated with social frailty.

Key words: Frailty, Social adjustment, Automobile driving, Environment design, Human activities
Introduction

Frailty is a biological syndrome involving the loss of physiological reserves in multiple systems and increased vulnerability to stressors \(^1\). Frailty is associated with physical limitations, hospitalization, and increased risk of mortality \(^2\). The concept of frailty includes multidimensional constructs including physical, psychological, and social factors \(^3\). Social frailty encompasses social aspects, such as individual, physical, environmental, and economic factors \(^4\). Social factors are important for understanding the state of frailty in older adults \(^5\). A meta-analysis on the association between social frailty and adverse outcomes reported that social frailty is a predictor of mortality, depressive symptoms, and functional disability \(^6\). However, appropriate management can prevent progression to disability, and increasing social activity may improve frailty \(^7,8\). Thus, while the issue of social factors is ingrained in the social aspects of frailty and triggers a variety of disabilities, focused interventions can prevent frailty and the risk of developing subsequent disabilities.

Driving a car is among the best ways for older adults to maintain mobility \(^9\). Although driving a car plays an important role in promoting social participation \(^10\), approximately 1.35 million deaths occur annually due to road traffic accidents \(^11\). Road traffic accidents are a public health problem, and efforts are underway to reduce their numbers \(^12\). In Japan, older drivers are more likely to be involved in fatal traffic accidents than their younger counterparts \(^13\). Strict driver licensing systems have also been adopted in some industrialized countries to prevent car accidents in older adults \(^14,15\). However, driving cessation by older adults makes it difficult for them to maintain their social participation \(^16,17\). Furthermore, the loss of independent transportation in older adults will lead to fewer outings and less time for social activities \(^18\). Driving cessation also tends to be associated with physical and social frailty \(^19,20\), whereas a combination of driving cessation and social frailty is associated with functional limitations \(^20\). Because older adults are more likely to experience social problems after stopping driving, their use of alternative means of transport may be important. Accordingly, previous studies
have reported the impact of transportation use on social participation after driving cessation \(^{21-23}\).

Thus, the use of transportation other than cars is assumed to be a modifiable factor in the association between driving cessation and social frailty. However, to date, no association has been reported between the frequency of transport use and social frailty among current non-drivers. Clarifying this relationship may serve as a new preventive measure against social frailty among current non-drivers. Therefore, the present study aimed to determine whether driving status and transport use are related to social frailty in middle-aged and older adults aged \(\geq 60\) years and investigate the relationship between the frequency of transport use and social frailty in current non-drivers.

**Material and methods**

**Study population**

A cross-sectional online survey was conducted with middle- and older adults aged \(\geq 60\) years in Japan using sampling from the Y-Cloud system, a crowdsourcing service launched by Yahoo Japan Corporation, Inc. (Tokyo, Japan). The survey was conducted in May 2022 and we received responses from 1,000 adults. Individuals with a history of cerebrovascular disease \((n = 13)\) or Parkinson's disease \((n = 1)\), those who responded “no response” to the item on sex in the survey \((n = 4)\), and those with missing data \((n = 5)\) were excluded. None of the respondents had a history of dementia or treatment. Finally, our analysis included data from 916 participants \((\text{mean age: } 65.1 \pm 4.6 \text{ years}; \text{ females: } 22.7\%\) with a driver's license and 61 participants \((\text{mean age: } 67.9 \pm 4.8 \text{ years}; \text{ females: } 59.0\%\) without a driver's license. This study was conducted in accordance with the guidelines of the Declaration of Helsinki and the research protocol was approved by the Institutional Review Board of the local university.

**Social frailty**
We assessed social frailty using previously reported tools. Although no consensus regarding the assessment of social frailty has been reached yet, the indicators used in this study focused on the social aspects of frailty. The following indicators were used as a measure of social frailty that assessed daily social activities, roles, and relationships: going out less frequently than last year (yes), visiting friends’ homes (no), feeling useful to family and friends (no), living alone (yes), and conversing with someone every day (no). Based on the number of applicable responses, the participants were classified into non-socially frail (0–1) and socially frail (≥2) groups. The definition of social frailty used in this study was supported by the literature review as an assessment tool with content validity.

Driving status and transport use

We assessed driving status and frequency during the previous month using an online questionnaire. First, based on responses regarding the current driving status, we defined the current driver group as participants who reported that they were “currently still driving.” Similarly, we defined the current non-driver group as those who responded, “returned driver's license,” “not renewed my driver's license,” “own a driver's license but do not drive,” or “not driving for other reasons.” Finally, we defined former non-drivers as those who responded “did not originally have a driver's license.”

We also surveyed the current driver group on the frequency of driving a car in the last month and asked them to select the most applicable of the following four options: almost every day, 3–4 times a week, about once a week, and once a month or less. Of these, we included those who responded that they drove a car “once a month or less” in the current non-driver group, as they were not considered to be driving a car as their daily mode of transportation.

Regarding transportation use, because the development of public transportation differs greatly between urban and suburban areas, we also considered bicycle use in addition to public transportation. The survey asked about the frequency of use of trains, buses, cabs, and bicycles. The respondents were
asked to choose the most appropriate option from among “every day,” “a few times a week,” “a few times a month,” “almost never,” and “never.” We categorized the respondents who answered, “every day” or “a few times a week” for any of the four transportation modes in the transport user group, and those who answered “a few times a month,” “almost ever,” or “never” for all four modes of transport in the transport non-user group. Based on the combination of driving status and transport use, we classified drivers into three groups: current drivers, current non-driver/transport users, and current non-driver/transport non-users. Finally, we classified former non-drivers into two groups—former non-driver/transport users and former non-driver/transport non-users—based on their transport use.

Other variables
The survey also asked the participants about their age, sex, body mass index (BMI), number of medicines taken (per day), depression, walking environment around their residence (walkability), place of residence, education history, continuous walking distance, and objective memory impairment. We calculated BMI from the questionnaire results by dividing weight (kg) by height (m)^2.

Polypharmacy was defined as the simultaneous administration of six or more medicines. The 6-item Kessler Scale (K6) was used to screen for psychological distress, in which higher total scores indicate more severe psychological problems. The Abbreviated Neighborhood Environment Walkability Scale (ANEWS) was used to measure the perceived ease of getting around by walking in the neighborhood living environment. Walkability is reportedly associated with frailty, physical activity, and disability occurrence. We applied cluster analysis to categorize the participants into high or low walkability groups. Regarding the area of residence, the respondents were asked to indicate the prefecture in which they currently resided; we dichotomized the areas of residence into “living in the three major metropolitan areas (Tokyo, Kinki, and Chubu)” and “living in the suburbs.” Regarding education history, the respondents were asked to select one of several items. We dichotomized responses of college or higher as “more than bachelor” and less than college as “less
than bachelor.” Continuous walking distance was evaluated as an indicator of walking ability and was categorized as “>1 km” or “<1 km”. Memory impairment was assessed based on participants’ response to the question regarding subjective memory complaints (SMC): “Have you ever experienced memory impairment that interfered with your daily life?” We considered those who answered “yes” to be SMC (+) 33).

Statistical analysis

For each group comparison between the three driver and two former non-driver groups, we performed a one-way analysis of variance (ANOVA) and the χ² test for continuous and categorical variables, respectively, to compare participant characteristics between groups. Post-hoc analyses were performed using the Bonferroni test.

We examined the relationships among driving status, transport use, and social frailty using multiple logistic regression. The association with social frailty in the current non-driver group was calculated with reference to the current driver group, while that in the transport non-user group was calculated with reference to the transport user group. We examined the associations with social frailty in the current driver, non-driver/transport user, and non-driver/transport non-user groups using the current driver group as a reference. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for all logistic regression analysis results. We included sex, age, polypharmacy, educational history, SMC, continuous walking distance, K6 score, place of residence, and walkability as covariates in the adjusted model. All analyses were performed using R (version 4.1.2), with statistical significance set at p < 0.05.

Results

Among drivers, 705 (77.0%) were classified as current drivers, 132 (14.4%) as current non-driver/transport users, and 79 (8.6%) as current non-driver/transport non-users. Among former non-
drivers, 32 (52.5%) were classified into the former non-driver/transport user and 29 (47.5%) into the
former non-driver/transport non-user groups. Table 1 presents the results of the ANOVA and post-hoc
analysis for each variable among the three groups of drivers. The current non-driver/non-transport user
group was significantly older than the current non-driver/transport user group (p = 0.011). The current
driver group included a significantly lower proportion of women than the current non-driver/transport
user (p = 0.002) and non-driver/transport non-user groups (p = 0.036). The current non-driver/transport
non-user group had a significantly higher rate of polypharmacy than the current non-driver/transport
user (p = 0.039) and current driver groups (p = 0.035). The current non-driver/transport user group had
significantly higher K6 scores than the current driver group (p = 0.030). The current driver group had a
significantly lower percentage of high walkability than the current non-driver/transport user (p < 0.001)
and current non-driver/transport non-user groups (p < 0.001). The current driver group had a
significantly lower percentage of residents in the three metropolitan areas than the current non-
non-driver/transport user (p = 0.002) and current non-driver/transport non-user groups (p = 0.036). Table 2
shows the results of the inter-group comparisons of former non-drivers; however, no items showed
statistically significant differences.

Table 3 shows the results of the χ² test and post-hoc analysis corresponding to the social frailty
rate in transport use for drivers and former non-drivers. Among the driver groups, social frailty was
observed in 52.1%, 62.1 %, and 69.6% of participants in the current driver, current non-
driver/transport user, and current non-driver/transport non-user groups, respectively. Post-hoc analysis
revealed a significantly higher prevalence of social frailty in the current non-driver/transport non-user
group compared with the current driver group (p = 0.010). Among former non-drivers, social frailty
was observed in 62.5% and 75.9% of participants in the former non-driver/transport user and former
non-driver/transport non-user groups, respectively, with no significant difference between the groups
(p=0.260).

Table 4 shows the results of the logistic regression analysis of the associations between driving
status, frequency of transportation use, and social frailty. The crude model demonstrated significant associations between the current non-driver (OR: 1.85, 95% CI 1.33–2.58) and transport non-user (OR: 1.32, 95% CI 1.00–1.75) groups and higher rates of social frailty. In the adjusted model, the current non-driver (OR: 1.72, 95% CI 1.19–2.49) and transport non-user (OR: 1.40, 95% CI 1.04–1.91) groups also showed significant associations with higher rates of social frailty.

Table 5 presents the results of the logistic regression analysis of the association between the three driver groups and social frailty. In the crude model, compared with the current driver group, the current non-driver/transport user (OR: 1.51, 95% CI 1.03–2.21) and current non-driver/transport non-user (OR: 2.11, 95% CI 1.27–3.49) groups showed statistically significant associations with higher rates of social frailty. However, in the adjusted model, compared with the current driver group, the current non-driver/transport user group showed no association with social frailty (OR: 1.34; 95% CI 0.88–2.06). Only the current non-driver/transport non-user group showed a significant association with a higher rate of social frailty (OR: 2.14, 95% CI 1.25–3.73).

Discussion

This study aimed to determine the association of driving status and transport use with social frailty, and to examine the association between the frequency of transport use and social frailty among middle-aged and older adults aged ≥60 years who were current non-drivers. Current non-driving and non-use transportation were significantly associated with higher social frailty rates. Non-driver use of transport was not associated with social frailty. However, we observed a higher prevalence of social frailty among current non-drivers who did not use transport.

Our results indicate that current non-drivers are more likely to experience social frailty than current drivers. Previous studies have shown that continued driving is beneficial for maintaining and promoting physical and mental health. Driving cessation in older drivers is associated with reduced social participation and a narrowing of life space. Although the increasing number of
driving accidents among older adults is a social concern, continued driving may effectively prevent social frailty. Continued driving should not be encouraged in older people at high risk of motor vehicle accidents. In such cases, alternative means of transportation, other than cars, are key to promoting social participation. In this study, the non-transport user group was more likely to experience social frailty than the transport user group. In previous studies, not only continued driving but also the frequent use of transport contribute to reduced loneliness, social participation, and fulfillment of social roles. The presence of accessible transportation other than cars is an important factor that determines accessibility to society. Frequent use of transport may also be associated with social frailty. Future longitudinal studies are needed to investigate the association between the frequency of transportation use and social frailty observed in the present study, as the cross-sectional design of the present study has a bidirectional association. Our investigation of the association between transportation use and social frailty among former non-drivers showed no association between the frequency of transport use and social frailty; however, the limited number of former non-drivers (n=61) in the analysis prevented multivariate analysis. Future studies with higher numbers of participants are needed to verify our findings. Additionally, longitudinal studies are needed to analyze the causal relationships.

Our analysis of the relationship between the frequency of transportation use and social frailty among drivers revealed that current non-driver/transport use was not associated with social frailty, whereas current non-driver/transport non-use was significantly associated with higher social frailty scores. Although an association between driving and social frailty has been previously reported, this study is the first to investigate the association between transportation use and social frailty among non-drivers. Although public transportation is the primary alternative to cars, these services face difficult conditions in Japan due to shrinking demand and a growing shortage of drivers, especially in rural areas. As the accessibility of public transportation varies significantly depending on the area
of residence, both public transportation and familiar and accessible means of transport play important
roles. For example, bicycle use increases physical activity, prevents functional limitations, \(^{32, 41}\) and
may contribute to improving the health of middle-aged and older people. However, older people are at
increased risk of bicycle accidents \(^{42}\) and bicycles can be a beneficial mode of public transportation if
they are used in accordance with transport rules. Ensuring transportation permeation by the local
transportation network and residential environment plays an important role as a new preventive
measure against social frailty. The results of the present study suggest that middle-aged and older
adults who have no means of transport other than cars after driving cessation may experience social
frailty. However, having a means of transport other than cars after driving cessation may aid outdoor
mobility and contribute to the fulfillment of social factors. Among current middle-aged and older non-
drivers, the frequency of transport use may be a factor associated with social frailty.

The results regarding social frailty in this study should be interpreted with caution. The reported
prevalence of social frailty in the Japanese population is 16.2\% \(^{43}\); however, the prevalence of social
frailty among all participants in this study was 55.0\% due to the dramatic changes in public health in
response to the spread of coronavirus disease 2019 (COVID-19) \(^{44}\). Social frailty in older adults may
increase due to limitations in social activity and social distancing \(^{45}\). Previous studies that assessed
social frailty using methods similar to those used in this study observed a trend toward an increased
prevalence of social frailty after the COVID-19 pandemic compared with before the pandemic \(^{46-48}\).
Therefore, the participants of the present study were likely similarly affected.

One strength of this study is that it considered differences in the development of transport in
different regions. This study provides important information for proposing comprehensive measures
to prevent social frailty. However, several limitations should be considered when interpreting the
results of the current study. First, participants were recruited from among specific Internet service
registrants. This study was limited to middle-aged and older adults who could access the Internet and
operate personal computers. Second, this study targeted a Japanese population; thus, the findings may
not be applicable worldwide. Third, this was a cross-sectional study and causal relationships were not investigated. Although infrequent transport use may be associated with social frailty, this was a cross-sectional study; therefore, the association was bidirectional. As the frequency of transport among current non-drivers affects the risk of developing social frailty, longitudinal studies are needed to clarify this causal relationship. Finally, the current study did not examine traffic use and social frailty among current drivers in detail, as it focused on the relationship between the frequency of transport use and social frailty after driving cessation. The proportions of participants with social frailty did not differ between the current driver and transport user and non-user groups (47.7% [n=239] vs. 53.3% [n=466]; \( \chi^2 \)-test; \( P=0.112 \)). However, further research is required to confirm this hypothesis. The results of this study showed that current non-drivers and infrequent transport use were significantly associated with higher rates of social frailty. In addition, compared with the current driver group, the current non-driver/transport user group showed no association with social frailty, whereas the current non-driver/transport non-user group was with social frailty. Among current non-drivers, the frequency of transport use may be associated with social frailty.

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