BMJ Open

Frailty and driving status associated with disability

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042468
Article Type:	Original research
Date Submitted by the Author:	06-Jul-2020
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Keywords:	GERIATRIC MEDICINE, EPIDEMIOLOGY, PUBLIC HEALTH

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Frailty and driving status associated with disability

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Abstract Word Count: 230, **Main Word Count**: 2340

Keywords: physical function, traffic, functioning and disability

Running Title: Disability, frailty, and drivng status

ABSTRACT

OBJECTIVES: To examine the relationship of driving status and frailty with disability in older adults.

DESIGN: A prospective study.

SETTING AND PARTICIPANTS: The study included 8,533 participants (mean age: 72.0±6.1 years [range: 60–98 years], women: 54.1%) in a community setting.

MEASURES: Driving status and frailty were assessed at baseline. Clinical definition of frailty was according to J-CHS index. Disability was prospectively determined using a record of Japanese long-term care insurance (LTCI).

RESULTS: During follow-up duration (mean: 23.5 months), 58 participants (0.7%) were regarded as moving out, 80 participants (0.9%) had died, and 311 participants (3.6%) were certified by LTCI. The proportion of disability was 1.3 % among not frail group and 5.4% among frail group. The proportion of disability was 2.5 % in participants who were currently driving and 7.7% in those not driving. Based on status of frailty and driving, participants were further classified into four groups: not frail and currently driving (n = 2905), not frail and not driving (n = 632), frail and currently driving (n = 3543), frail and not driving (n = 1315). Compared to older adults who are not frail and driving, the combined status of frail and not driving (adjusted HR: 2.28 [95%CI: 1.47-3.52]) and frail with driving (HR: 1.91 [1.30-2.81]) were risk factors for disability.

CONCLUSIONS: Not driving and frail was a risk of disability in community-dwelling older adults.

Article Summary

Strengths and limitations of this study

- From a large population study of over 8000 older adults, current not driving increased risk of disability incidence.
- The effects of driving were observed among participants who were frail, while not driving did not increase the risk of disability among participants who were not frail.
- The primary limitations were a short follow-up duration.

INTRODUCTION

Extending healthy life expectancy and diminishing the duration of life with disability helps to decrease the health burden on society.[1] Frailty is regarded as a prodromal stage of disability and has a high risk of adverse health outcomes, including disability. Frailty is a reversible status; someone's health could become robust again.[2] Although frailty is a complex age-related clinical condition, adequate assessment of risk and preventive actions could help providers disrupt the progression from frail to disabled.[3]

Driving is a critical resource in supporting an active life style in older adults. In fact, driving cessation increases the risk of disability.[4, 5] However, whether the combined condition of not driving and being frail also elevated the risk of disability is unclear. More older adults are driving cars, but they are also having more accidents, especially in super-aged societies, like Japan.[6] Adequate evaluation of driving ability is required, but driving cessation with insufficient cause can potentially increase disability. Thus, our study aimed to elucidate how frailty and driving status affects disability risks.

METHODS

Participants

Participants in this study were from the National Center for Geriatrics and Gerontology – Study of Geriatric Syndromes[7], which aims to establish a screening system for geriatric syndromes and validate evidence-based interventions for preventing these syndromes. Participants were collected from surveys conducted in 2015–2017; 9,701 individuals aged 60 years or over were eligible. The survey was regarded as the baseline and prospectively collected data was used for a follow-up duration of approximately two years (23.5 months). Exclusion criteria included: diagnoses of dementia, stroke, and Parkinson's disease; being unable to independently perform basic activities of daily living; being certified with long-term care insurance (LTCI) in Japan before the survey; and having missing values for analysis. All participants provided written informed consent, and the ethics committee of the National Center for Geriatrics and Gerontology approved this study (770, 791).

Frailty

The definition of frailty used in this study was the Japanese CHS (J-CHS) index,[8-10] according to CHS index criteria.[2] The components of frailty in the J-CHS index are same as the original CHS index: shrinking (weight loss), weakness, poor endurance (exhaustion), slowness, and low activity. Weight loss was collected by a question from the Kihon Checklist,[11] with the question "Have you lost 2 kg or more in the past six months?" A "yes" answer indicated that participants had experienced weight loss. Weakness was defined as low muscle strength based on grip strength, measured using a

Smedley-type handheld dynamometer (Takei Ltd, Niigata, Japan). Sex-specific cut-offs of low muscle strength were < 26 kg in men and < 18 kg in women.[8, 9, 12] Exhaustion was assessed using a question from the Kihon Checklist:[11] a "yes" answer to the question, "In the last two weeks, have you felt tired for no reason?" indicated that participants had exhaustion or poor endurance. Slowness was defined as slow walking speed under normal conditions. Participants were asked to walk on a straight, 6.4 m walkway, on a flat floor with their usual gait speed. Gait time was measured over a 2.4 m distance between marks at 2.0 m and 4.4 m from the start of the walkway, and the mean gait speed (m/s) was calculated. The cut-off value of slowness was less than 1.0 m/s.[8, 9] Low activity level was also measured using the questionnaire and indicated through a response of "no" to both: "Do you engage in moderate levels of physical exercise or sports aimed at health?" and "Do you engage in low levels of physical exercise aimed at health?"[8, 9] Based on the values of these five components (weight loss, weakness, exhaustion, slowness, and low activity), our study assigned "frail" to values of 1 and over, including pre-frailty and frailty.[8, 9]

Driving status

The survey asked participants about their driving status. To determine driving status, current status of driving license (without license, surrendered, not renewed, has license but not driving, and currently driving with license) was reviewed. In our study, the status of currently driving with license was regarded as currently driving, and all other statuses were regarded as not driving.

Disability

LTCI certification in all participants was monitored throughout follow-up. LTCI certifies a person as "Support Level 1 or 2" if he or she needs support for daily activities or "Care Level 1, 2, 3, 4, or 5" if they need continuous care.[13] Beneficiaries of the LTCI can use multiple services for which they are eligible. They can use more services than are covered if they pay all the costs for services beyond the maximum level.[13, 14] In our study, becoming disabled was defined as a new LTCI certification at any level. If we were unable to follow up and assess for incident disability, this was treated as censored data, i.e., moving out of the other city and death. We monitored this information through monthly updates. We defined the follow-up period as beginning at the time we conducted the survey at baseline (mean follow-up duration: 23.5 months [max: 24.0 months]).

Covariates

To understand participants' characteristics, demographic data, medical condition, and life style were assessed. Regarding demographic data, age and sex were collected. For medical condition, participants were interviewed about their medication use by well-trained nurses or other medical staff, and medication numbers were collected. Cognitive function was assessed through the Mini-Mental State Examination (MMSE).[15] Depressive symptoms were assessed using the geriatric depression scale (15 items version).[16] In addition, going out less frequently was assessed by a question from the Kihon Checklist.[11]

Statistical Analysis

Variables at baseline were compared between participants with and without disability

during the follow-up duration, using an unpaired *t*-test or χ^2 test. Participants were classified into four groups according to their baseline status of driving and frailty: not frail and currently driving, not frail and not driving, frail and currently driving, frail and not driving.

To examine the association of frailty and driving status with the risk of disability, Kaplan–Meier survival risk assessments were used to plot cumulative survival function, and the results for each group were compared using log rank tests. The objective variable was set as incident disability and the explanatory variable was four groups based on frail and driving. In addition, Cox proportional hazards regression models was used to test the association. For incident disability, hazard ratios (HR) of the frail group compared to the not frail group and the not driving group compared to the driving group were calculated respectively. Four groups were also set as the explanatory variable, with the without frail and currently driving group as reference. These analyses were conducted in crude and adjusted models, including covariates. Each model in Cox proportional hazards regression analysis calculated HR and 95% confidence intervals (CI). All analyses were performed using SPSS statistics software, Version 20 (IBM Corp., Chicago, IL, USA). Statistical significance was set at $p < 0.05$ in all analyses.

RESULTS

From 9,701 eligible participants, 8,533 participants (mean age: 72.0 ± 6.1 years [age range: 60–98 years], women: 54.1%) were matched with criteria and analyzed in this study. During the follow-up duration, 58 participants (0.7%) were regarded as moving out, 80 participants (0.9%) died, and 311 participants (3.6%) were certified by LTCI. Participants with disability, compared to those without disability, were older, took more medications, went out less frequently, and had higher scores on the geriatric depression scale and lower scores on MMSE (Table 1, all $p < 0.001$). In addition, participants with disabilities were more likely to be frail and less likely to be currently driving (both $p < 0.001$).

Table 1. Characteristics of participants with disability and without during follow-up duration

Variables	Without disability (n = 8084)	With disability (n = 311)	*p*-value
Age, years	71.7 (5.9)	79.2 (6.3)	< 0.001
Sex (women), %	54.1	56.3	0.450
Medication numbers	2.7 (2.6)	3.8 (2.8)	< 0.001
Less frequent going out, %	13.2	33.5	< 0.001
Currently driving, %	77.8	51.8	< 0.001
Status of frailty			< 0.001
Robust, %	43.2	15.1	
Pre frailty, %	50.2	52.4	

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Frailty, %	6.6	32.5	
Geriatric Depression Score, score	2.6 (2.5)	3.8 (2.7)	< 0.001
Mini-Mental State Examination, score	27.3 (2.4)	25.0 (3.6)	< 0.001

Note: Values are mean (standard deviations) or proportions. The total number of participants was 8533. Data in this Table excluded 138 participants (58 participants regarded as moving out and 80 participants died).

The proportion of incident disability during follow-up duration was dependent on status of frailty and driving (Figure 1). The proportion of participants with disability was 1.3% in the not frail group and 5.4% in the frail group. The proportion of participants with disability who were currently driving was 2.5%, and the proportion of participants who were not driving was 7.7%. Based on their status of frailty and driving, participants were further classified into four groups: not frail and currently driving (n = 2905), not frail and not driving (n = 632), frail and currently driving (n = 3543), and frail and not driving (n = 1315). According to four groups based on frailty and driving status, participants who were not frail and currently driving had lowest proportion of disability (1.2%) and participants in frail and not driving had highest proportion of disability (10.4%). Survival risk based on log-rank test did not show a difference between participants from the not frail and currently driving group and the not frail and not driving (p = 0.077). There were also not significant differences between participants from not frail and not driving and from frail and currently driving, (p = 0.051). Other intergroup results did show differences (p < 0.001). From the analysis using Cox proportional hazards regression models, the frail group had an increased risk of disability (crude HR

4.15 [95%CI: 3.04-5.66]), as did not driving (crude HR 3.15 [95%CI: 2.52-3.93]). In addition, compared to not frail and currently driving group, participants from frail and currently driving ($p = 0.001$), and participants from frail and not driving ($p < 0.001$), had an increased risk of incident disability (Table 2).

Table 2. Association of status in frailty and driving with disability

Variables	Unadjusted HR	(95% CI)	*p*	Adjusted HR	(95% CI)	*p*
Not frail and currently driving		Reference				
Not frail and not driving	1.77	(0.93-3.35)	0.081	1.09	(0.57-2.09)	0.802
Frail and currently driving	3.10	(2.12-4.52)	< 0.001	1.91	(1.30-2.81)	0.001
Frail and not driving	9.25	(6.35-13.47)	< 0.001	2.28	(1.47-3.52)	< 0.001
Age				1.14	(1.12-1.16)	< 0.001
Sex (reference: men)				0.89	(0.69-1.16)	0.392
Mini-Mental State Examination				0.89	(0.86-0.92)	< 0.001
Medication numbers				1.03	(0.99-1.07)	0.136
Less frequently going out (reference: yes)				0.66	(0.51-0.85)	0.001
Geriatric Depression Scale				1.05	(1.01-1.09)	0.018

HR: hazard ratio; CI: confidence interval. The total number of participants was 8533. Data in this Table excluded 138 participants (58 participants regarded as moving out and 80 participants died).

DISCUSSION

Our study examined the association of frailty and driving status with the risk of disability among older adults. The proportion of incident disability was higher among those whose status was frail and not driving. The effects of driving were observed among participants who were frail, while not driving did not increase the risk of disability among participants who were not frail. This result remained even after adjustment with covariates.

Our study revealed that being frail was a risk of incident disability, which is in line with previous research. Numerous studies have indicated that frailty caused disability and other adverse health outcomes.[2] When we studied data from another section of the NCGG-SGS in 2011-12 with a similar follow-up duration (about 2 years), we saw a similar risk for frailty to cause disability,[10] although the data in 2011-2012 did not have detailed assessments regarding driving. Our study is in accordance with similar studies and expands the previous evidence regarding frailty. Driving status had been associated with a risk of disability, particularly amongst frail participants. Driving a motor vehicle has a beneficial role in maintaining life space and activities in older adults. In fact, having a valid driving license was associated with reduced hazard of life-space constriction[17] and not driving increased restriction of life-space restriction.[18] In addition, having a combined status of frail and not driving created a high risk of disability compared to the other status. Not driving also caused functional decline in older adults, particularly when driving ceased. A prospective study revealed that stopping driving or reducing the distance driven was related to several functional declines and a decline in instrumental activities of daily living.[19] Furthermore, not driving was associated with higher risk of mortality.[20, 21] O'Connor suggested the

relationship may be explained by health difficulties in social, physical, and general health to accompany or follow driving cessation.[20]

The strength of this study was that it was conducted in a large population study with a prospective design. Our study also had limitations. In this study, disability was defined as certification of LTCI. LTCI could not distinguish causes for the disability certification systematically. For example, we could not objectively distinguish between mobility and cognitive disabilities.

In conclusion, frailty and not driving status were associated with the risk of disability. Not driving increased the risk of disability, particularly among frail older adults. The status of driving should be considered to assess the risk of disability.

ACKNOWLEDGMENT

We thank the Obu city and Takahama city office for help with participant recruitment.

CONTRIBUTORSHIP

TD: acquisition of the data, statistical analysis, interpretation of the data, and drafting of the manuscript. HS: study design and concept, and drafting and revising of the manuscript. IH and KT: acquisition of the data, statistical analysis, interpretation of the data, and drafting of the manuscript. NS and KS: acquisition and interpretation of the data and drafting of the manuscript.

COMPETING INTERESTS

None of the authors have any financial, personal, or potential conflict of interest with the material presented in this article.

DATA AVAILABILITY STATEMENT

No data are available.

FUNDING

This work was supported by AMED under Grant Number (15dk0207004h0203, 15dk0107003h0003); a Grant-in-Aid for Scientific Research (B) (grant number 23300205); the Funds of Obu City Local Government; and Research Funding for Longevity Sciences (26-33, 29-31, 30-7) from the National Center for Geriatrics and Gerontology, Japan.

REFERENCES

1 GBD 2017 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018;392:1859-922. doi: 10.1016/s0140-6736(18)32335-3

2 Fried LP, Tangen CM, Walston J, *et al.* Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001;56:M146-56. doi: 10.1093/gerona/56.3.M146

3 Hoogendijk EO, Afilalo J, Ensrud KE, *et al.* Frailty: implications for clinical practice and public health. *Lancet* 2019;394:1365-75. doi: 10.1016/s0140-6736(19)31786-6

4 Hirai H, Ichikawa M, Kondo N, *et al.* The risk of functional limitations after driving cessation among older Japanese adults: the JAGES cohort study. *J Epidemiol* 2019. doi: 10.2188/jea.JE20180260

5 Shimada H, Makizako H, Tsutsumimoto K, *et al.* Driving and Incidence of Functional Limitation in Older People: A Prospective Population-Based Study. *Gerontology* 2016;62:636-43. doi: 10.1159/000448036

6 National Police Agency. The White Paper on Police 2019. doi:

7 Shimada H, Tsutsumimoto K, Lee S, *et al.* Driving continuity in cognitively impaired older drivers. *Geriatr Gerontol Int* 2016;16:508-14. doi: 10.1111/ggi.12504

8 Satake S, Shimada H, Yamada M, *et al.* Prevalence of frailty among community-dwellers and outpatients in Japan as defined by the Japanese version of the Cardiovascular Health Study criteria. *Geriatr Gerontol Int* 2017;17:2629-34. doi: 10.1111/ggi.13129

9 Shimada H, Makizako H, Doi T, *et al.* Incidence of Disability in Frail Older Persons

With or Without Slow Walking Speed. *J Am Med Dir Assoc* 2015;16:690-6. doi: 10.1016/j.jamda.2015.03.019

10 Makizako H, Shimada H, Doi T, *et al.* Impact of physical frailty on disability in community-dwelling older adults: a prospective cohort study. *BMJ Open* 2015;5:e008462. doi: 10.1136/bmjopen-2015-008462

11 Fukutomi E, Okumiya K, Wada T, *et al.* Relationships between each category of 25-item frailty risk assessment (Kihon Checklist) and newly certified older adults under Long-Term Care Insurance: A 24-month follow-up study in a rural community in Japan. *Geriatr Gerontol Int* 2015;15:864-71. doi: 10.1111/ggi.12360

12 Chen LK, Liu LK, Woo J, *et al.* Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc* 2014;15:95-101. doi: 10.1016/j.jamda.2013.11.025

13 Tsutsui T, Muramatsu N. Japan's universal long-term care system reform of 2005: containing costs and realizing a vision. *J Am Geriatr Soc* 2007;55:1458-63. doi: 10.1111/j.1532-5415.2007.01281.x

14 Tsutsui T, Muramatsu N. Care-needs certification in the long-term care insurance system of Japan. *J Am Geriatr Soc* 2005;53:522-7. doi: 10.1111/j.1532-5415.2005.53175.x

15 Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189-98. doi: 0022-3956(75)90026-6

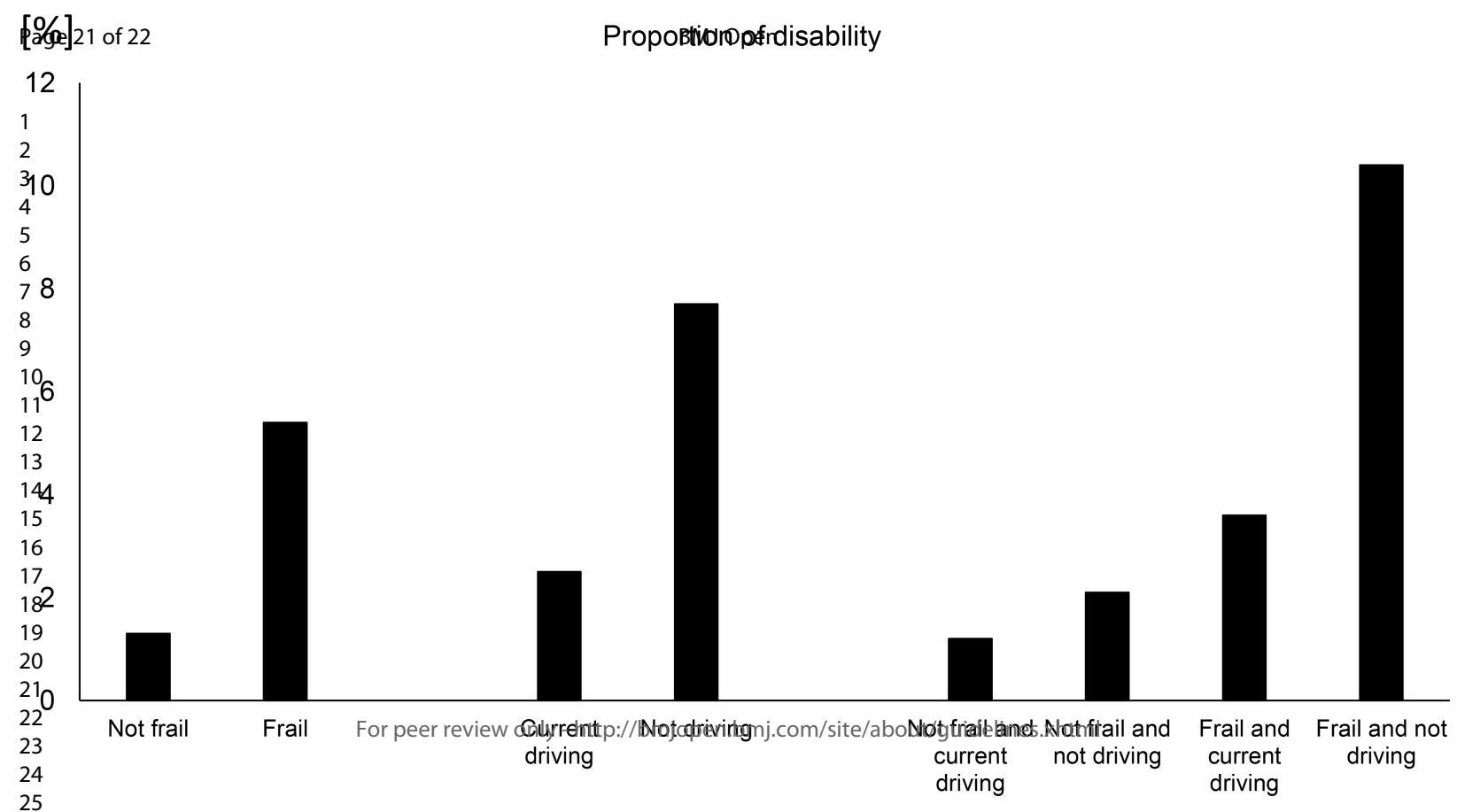
16 Yesavage JA. Geriatric Depression Scale. *Psychopharmacol Bull* 1988;24:709-11. doi:

17 Shah RC, Maitra K, Barnes LL, *et al.* Relation of driving status to incident life space

297 constriction in community-dwelling older persons: a prospective cohort study. *J Gerontol*
298 *A Biol Sci Med Sci* 2012;67:984-9. doi: 10.1093/gerona/gls133
299 18 Tsuji T, Rantakokko M, Portegijs E*, et al.* The effect of body mass index, lower
300 extremity performance, and use of a private car on incident life-space restriction: a two-
301 year follow-up study. *BMC Geriatr* 2018;18:271. doi: 10.1186/s12877-018-0956-3
302 19 Marie Dit Asse L, Fabrigoule C, Helmer C*, et al.* Automobile driving in older adults:
303 factors affecting driving restriction in men and women. *J Am Geriatr Soc* 2014;62:2071-8.
304 doi: 10.1111/jgs.13077
305 20 O'Connor ML, Edwards JD, Waters MP*, et al.* Mediators of the association between
306 driving cessation and mortality among older adults. *J Aging Health* 2013;25:249s-69s.
307 doi: 10.1177/0898264313497796
308 21 Edwards JD, Perkins M, Ross LA*, et al.* Driving status and three-year mortality
309 among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* 2009;64:300-5.
310 doi: 10.1093/gerona/gln019

LEGENDS

Figure 1. Proportion of disability compared between status of frail and driving.



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	9
		(*e*) Describe any sensitivity analyses	7-89
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-12
		(b) Give reasons for non-participation at each stage	9-12
		(c) Consider use of a flow diagram	9-12
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-12
		(b) Indicate number of participants with missing data for each variable of interest	9-12
		(c) Summarise follow-up time (eg, average and total amount)	9-12
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-12
		(*b*) Report category boundaries when continuous variables were categorized	9-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	9-12
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Frailty and driving status associated with disability: A 24-month follow-up longitudinal study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042468.R1
Article Type:	Original research
Date Submitted by the Author:	19-Jan-2021
Complete List of Authors:	Doi, Takehiko; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science Tsutsumimoto, Kota; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science Ishii, Hideaki; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science Nakakubo, Sho; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science Kurita, Satoshi; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science Shimada, Hiroyuki; National Center for Geriatrics and Gerontology, Department of Preventive Gerontology, Center for Gerontology and Social Science
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Geriatric medicine
Keywords:	GERIATRIC MEDICINE, EPIDEMIOLOGY, PUBLIC HEALTH

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Frailty and driving status associated with disability: A 24-month follow-up longitudinal study

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Abstract Word Count: 241, **Main Word Count**: 2821

Keywords: physical function, traffic, functioning and disability

Running Title: Disability, frailty, and driving status

ABSTRACT

OBJECTIVES: To examine the relationship of driving status and frailty with disability in older adults.

DESIGN: A prospective study.

SETTING AND PARTICIPANTS: The study included 8,533 participants (mean age: 72.0±6.1 years [range: 60–98 years], women: 54.1%) in a community setting.

MEASURES: Driving status and frailty were assessed at baseline. The clinical definition of frailty was used according to the J-CHS index. Disability was prospectively determined using a record of Japanese long-term care insurance (LTCI).

RESULTS: During the follow-up period (mean duration: 23.5 months), 58 participants (0.7%) were regarded as moving out of the city, 80 participants (0.9%) had died, and 311 participants (3.6%) were certified by LTCI. The proportion of disability was 1.3% among the not-frail group and 5.4% among the frail group. The proportion of disability was 2.5% in participants who were currently driving and 7.7% in those not driving. Based on frailty status and driving, participants were further classified into four groups: not frail and currently driving (n = 2905), not frail and not driving (n = 632), frail and currently driving (n = 3543), and frail and not driving (n = 1315). Compared to older adults who are not frail and driving, the combined status of frail and not driving (adjusted HR: 2.28 [95%CI: 1.47–3.52]) and frail and driving (HR: 1.91 [1.30–2.81]) were risk factors for disability.

CONCLUSIONS: Not driving and frail were associated with a risk of disability in community-dwelling older adults.

Article Summary

Strengths and limitations of this study

- This is a large population study including over 8,000 older adults.
- Frailty was defined by the J-CHS index.
- Incident disability was followed over time using data from long-term care insurance.
- The primary limitation was the short follow-up duration.
- Baseline data were collected from health checkups that had a selection bias.

INTRODUCTION

Extending healthy life expectancy and diminishing the duration of life with disability help to decrease health burdens on society.[1] Frailty is regarded as a prodromal stage of disability and has a high risk of adverse health outcomes, including disability. Frailty is a reversible status; someone's health could become robust again.[2] Although frailty is a complex age-related clinical condition, adequate assessment of risk and preventive actions could help providers disrupt the progression from frail to disabled.[3]

Driving is a critical resource in supporting an active lifestyle in older adults. In fact, driving cessation increases the risk of disability.[4, 5] However, whether the combined condition of not driving and being frail also elevates the risk of disability is unclear. More older adults are driving cars, but they are also having more accidents, especially in super-aged societies like Japan.[6] Adequate evaluation of driving ability is required, but driving cessation with insufficient cause can potentially increase disability. Thus, our study aimed to elucidate how frailty and driving status affect disability risks.

METHODS

Participants

Participants in this study were from the National Center for Geriatrics and Gerontology – Study of Geriatric Syndromes,[7] which aims to establish a screening system for geriatric syndromes and validate evidence-based interventions for preventing these syndromes. Participants were collected from surveys conducted in 2015–2017; 9,701 individuals aged 60 years or over were eligible. The survey was regarded as the baseline and prospectively collected data was used for a follow-up duration of approximately two years (23.5 months). Data to be certified with long-term care insurance (LTCI) were collected during the follow-up period. Other variables including frailty, driving status, and covariates were assessed at baseline. Exclusion criteria included diagnoses of dementia, stroke, and Parkinson's disease; being unable to independently perform basic activities of daily living; being certified with LTCI in Japan before the survey; and having missing values for analysis. All participants provided written informed consent, and the ethics committee of the National Center for Geriatrics and Gerontology approved this study (770, 791).

Frailty

The definition of frailty used in this study was the Japanese CHS (J-CHS) index[8-10] according to CHS index criteria.[2] The components of frailty in the J-CHS index are the same as those in the original CHS index: shrinking (weight loss), weakness, poor endurance (exhaustion), slowness, and low activity. Weight loss was collected by a question from the Kihon Checklist[11] with the question "Have you lost 2 kg or more in the past six months?" A "yes" answer indicated that participants had experienced weight loss. The Kihon Checklist is a self-administered questionnaire to identify frail older adults

who are at risk of being newly certified for LTCI in the near future consisting of 25 items in the following categories: physical strength, nutritional status, oral function, cognitive function, houseboundness, and depression risk.[11] Weakness was defined as low muscle strength based on grip strength, measured using a Smedley-type handheld dynamometer (Takei Ltd, Niigata, Japan). Sex-specific cut-offs of low muscle strength were < 26 kg in men and < 18 kg in women.[8, 9, 12] Exhaustion was assessed using a question from the Kihon Checklist:[11] a "yes" answer to the question "In the last two weeks, have you felt tired for no reason?" indicated that participants had exhaustion or poor endurance. Slowness was defined as slow walking speed under normal conditions. Participants were asked to walk on a straight 6.4 m walkway on a flat floor with their usual gait speed. Gait time was measured over a 2.4 m distance between marks at 2.0 m and 4.4 m from the start of the walkway, and the mean gait speed (m/s) was calculated. The cut-off value of slowness was less than 1.0 m/s.[8, 9] Low activity level was also measured using the questionnaire and indicated through a response of "no" to both: "Do you engage in moderate levels of physical exercise or sports aimed at health?" and "Do you engage in low levels of physical exercise aimed at health?"[8, 9] Based on the values of these five components (weight loss, weakness, exhaustion, slowness, and low activity), our study assigned "frail" to values of 1 and over, including pre-frailty (1–2) and frailty (3 or over).[8, 9]

Driving status

The survey asked participants about their driving status. To determine driving status, current status of driving license (without license [never having a license], surrendered license, license not renewed, has license but not driving, and currently driving with

license) was reviewed. In our study, the status of currently driving with license was regarded as currently driving, and all other statuses were regarded as not driving.

Disability

LTCI certification in all participants was monitored throughout the follow-up period. LTCI certifies a person as "Support Level 1 or 2" if he or she needs support for daily activities or "Care Level 1, 2, 3, 4, or 5" if they need continuous care.[13] Beneficiaries of the LTCI can use multiple services for which they are eligible. They can use more services than are covered if they pay all the costs for services beyond the maximum level.[13, 14] In our study, becoming disabled was defined as a new LTCI certification at any level. If we were unable to follow up and assess for incident disability (due to moving out of the city and death), this was treated as censored data. We monitored this information through monthly updates. We defined the follow-up period as beginning at the time we conducted the survey at baseline (mean follow-up duration: 23.5 months [max: 24.0 months]).

Covariates

To understand participants' characteristics, demographic data, medical condition, and lifestyle were assessed. Regarding demographic data, age and sex were collected. For medical condition, participants were interviewed about their medication use by well-trained nurses or other medical staff and medication numbers were collected. Cognitive function was assessed through the Mini-Mental State Examination (MMSE).[15] Depressive symptoms were assessed using the geriatric depression scale (15 items version).[16] In addition, going out less frequently was assessed by a question from the

Kihon Checklist.[11]

Statistical Analysis

Variables at baseline were compared between participants with and without disability during the follow-up period using an unpaired *t*-test or χ^2 test. Participants were classified into four groups according to their baseline status of driving and frailty: not frail and currently driving, not frail and not driving, frail and currently driving, and frail and not driving.

To examine the association of frailty and driving status with the risk of disability, Kaplan–Meier survival risk assessments were used to plot cumulative survival function, and the results for each group were compared using log-rank tests. The objective variable was set as incident disability, and the explanatory variable was four groups based on frailty status and driving. In addition, Cox proportional hazards regression models were used to test the association. For incident disability, hazard ratios (HR) of the frail group compared to the not-frail group and the not-driving group compared to the driving group were set respectively between models as well as in the same model. Four groups were also set as the explanatory variable, with the not-frail and currently driving group as reference. These analyses were conducted in crude and adjusted models, including covariates. In addition, for a sensitivity analysis, Cox proportional hazards regression analysis was also conducted to establish a different definition of disability. In the sensitivity analysis, disability was defined to be certified as "Care Level 1 or higher," and other variables were set in the same manner. Each model in the Cox proportional hazards regression analysis calculated HR and 95% confidence intervals (CI). All analyses were performed using SPSS statistics software, Version 20 (IBM Corp., Chicago, IL, USA).

Statistical significance was set at $p < 0.05$ in all analyses.

Patient and Public Involvement

This study was conducted without patient or public involvement.

RESULTS

From 9,701 eligible participants, 8,533 participants (mean age: 72.0 ± 6.1 years [age range: 60–98 years], women: 54.1%) were matched with criteria and analyzed in this study. During the follow-up period, 58 participants (0.7%) were regarded as moving out, 80 participants (0.9%) died, and 311 participants (3.6%) were certified by LTCI. Participants with disability, compared to those without disability, were older, took more medications, went out less frequently, and had higher scores on the geriatric depression scale and lower scores on MMSE (Table 1, all $p < 0.001$). In addition, participants with disabilities were more likely to be frail and less likely to be currently driving (both $p < 0.001$).

Table 1. Characteristics of participants with disability and without during the follow-up period

Variables	Without disability (n = 8084)	With disability (n = 311)	*p*-value
Age, years	71.7 (5.9)	79.2 (6.3)	< 0.001
Sex (women), %	54.1	56.3	0.450
Medication numbers	2.7 (2.6)	3.8 (2.8)	< 0.001
Less frequent going out, %	13.2	33.5	< 0.001
Currently driving, %	77.8	51.8	< 0.001
Status of frailty			< 0.001
Robust, %	43.2	15.1	
Pre-frailty, %	50.2	52.4	

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Frailty, %	6.6	32.5	
Geriatric Depression Score, score	2.6 (2.5)	3.8 (2.7)	< 0.001
Mini-Mental State Examination, score	27.3 (2.4)	25.0 (3.6)	< 0.001

Note: Values are means (standard deviations) or proportions. The total number of participants was 8,533. Data in this table excluded 138 participants (58 participants were regarded as moving out and 80 participants had died).

The proportion of incident disability during the follow-up period was dependent on the status of frailty and driving (Figure 1). The proportion of participants with disability was 1.3% in the not-frail group and 5.4% in the frail group. The proportion of participants with disability who were currently driving was 2.5%, and the proportion of participants who were not driving was 7.7%. Based on their status of frailty and driving, participants were further classified into four groups: not frail and currently driving (n = 2905), not frail and not driving (n = 632), frail and currently driving (n = 3543), and frail and not driving (n = 1315). Among those four groups, participants who were not frail and currently driving had the lowest proportion of disability (1.2%) and participants who were frail and not driving had the highest proportion of disability (10.4%). Survival risk based on log-rank test did not show a difference between participants from the not-frail and currently driving group and the not-frail and not-driving group ($p = 0.077$). There were also no significant differences between participants from the not-frail and not-driving group and from the frail and currently driving group ($p = 0.051$). Other intergroup results did show differences ($p < 0.001$). From the analysis using Cox proportional hazards regression models, the frail group had an increased risk of disability (crude HR 4.15

[95%CI: 3.04–5.66]), as did not driving (crude HR 3.15 [95%CI: 2.52–3.93]). In the model that set frailty and driving status together, similar results were shown for frailty (HR 3.72 [95%CI: 2.72–5.07]) and not driving (HR 2.79 [95%CI: 2.23–3.49]). In addition, compared to the not-frail and currently driving group, participants from the frail and currently driving group ($p = 0.001$), and those from the frail and not-driving group ($p < 0.001$), had an increased risk of incident disability (Table 2). For a sensitivity analysis, a different definition of disability (being certified as "Care Level 1 or higher") was used. Adjusted HR for incident disability was higher in the frail and not-driving group (HR 1.87 [95%CI: 1.06–3.31]), and other groups (not frail and not driving; frail and currently driving) were not significantly associated with disability.

Table 2. Association of status in frailty and driving with disability

Variables	Unadjusted HR	(95% CI)	*p*	Adjusted HR	(95% CI)	*p*
Not frail and currently driving		Reference				
Not frail and not driving	1.77	(0.93-3.35)	0.081	1.09	(0.57-2.09)	0.802
Frail and currently driving	3.10	(2.12-4.52)	< 0.001	1.91	(1.30-2.81)	0.001
Frail and not driving	9.25	(6.35-13.47)	< 0.001	2.28	(1.47-3.52)	< 0.001
Age				1.14	(1.12-1.16)	< 0.001
Sex (reference: men)				0.89	(0.69-1.16)	0.392
Mini-Mental State Examination				0.89	(0.86-0.92)	< 0.001
Medication numbers				1.03	(0.99-1.07)	0.136
Less frequently going out (reference: yes)				0.66	(0.51-0.85)	0.001
Geriatric Depression Scale				1.05	(1.01-1.09)	0.018

HR: hazard ratio; CI: confidence interval. The total number of participants was 8533. Data in this Table excluded 138 participants (58 participants regarded as moving out and 80 participants died). The definition of frail for group classification was pre-frailty or frailty.

DISCUSSION

Our study examined the association of frailty and driving status with the risk of disability among older adults. The proportion of incident disability was higher among those with a status of frail and not driving. The effects of driving were observed among participants who were frail, while not driving did not increase the risk of disability among participants who were not frail. This result remained even after adjustment with covariates.

Our study revealed that being frail was associated with a risk of incident disability, which is in line with previous research. Numerous studies have indicated that frailty caused disability and other adverse health outcomes.[2] When we studied data from another section of the NCGG-SGS in 2011-12 with a similar follow-up duration (about 2 years), we saw a similar risk for frailty to cause disability,[10] although the data in 2011–2012 did not have detailed assessments regarding driving. Our study is in accordance with similar studies and expands the previous evidence regarding frailty. Driving status had been associated with a risk of disability, particularly among frail participants. Driving a motor vehicle has a beneficial role in maintaining life space and activities in older adults. In fact, having a valid driving license was associated with reduced hazard of life-space constriction[17] and not driving increased the restriction of life-space restriction.[18] In addition, having a combined status of frail and not driving created a high risk of disability compared to the other statuses. Not driving also caused functional decline in older adults, particularly when driving ceased. A prospective study revealed that stopping driving or reducing the distance driven was related to several functional declines and a decline in instrumental activities of daily living.[19] Furthermore, not driving was associated with a higher risk of mortality.[20, 21]

O'Connor suggested that the relationship may be explained by health difficulties in social, physical, and general health to accompany or follow driving cessation.[20]

Our results brought to light new ideas about the assessment of driving continuity in older adults. By engaging in several activities associated with driving, older adults may successfully age. The current system in Japan for adults aged 70 years or over, established by Japan's National Police Agency, requires individuals to attend a lecture on driving operation, undergo vision tests, attend an on-road lecture, and be screened for cognitive function.[22] If they are appropriately diagnosed as having dementia, they are unable to renew their licenses.[22] The evaluation of physical function (i.e., frailty) should be considered as part of the assessments used to renew licenses. Furthermore, age-related changes that affect driving skill are varied and occurred gradually. Thus, offering restricted licenses (e.g., restricting legal driving times to daylight or good weather) should be considered before cessation. To introduce such limited licenses may require detailed assessments in addition to the current system.

The strength of this study was that it was conducted in a large population study with a prospective design. Our study also has some limitations. In this study, disability was defined as certification of LTCI. LTCI cannot systematically distinguish causes for the disability certification. For example, we could not objectively differentiate between mobility and cognitive disabilities. In addition, LTCI has several levels (Support Level 1–2, Care Level 1–5) based on the results of standardized assessments and a final decision from the expert board (Nursing Care Needs Certification Board). Characteristics of participants with disabilities are thus varied and depend on certified levels. Further study including more participants is required to compare the differences of each certified level. Furthermore, the data used in our study were derived from the

NCGG-SGS database based on invitational health checkups among Japanese older adults. Such checkups have a selection bias in that participants may have a higher health literacy. Therefore, the results of our study are not easily generalizable. In addition, data in this study could not clarify casual association between driving and disability. Reverse causation (that functional decline with disability affects driving cessation) is also possible. To examine reverse causation, data regarding changes in function, incident disability, and future driving cessation should be analyzed. Next, our study used the J-CHS index to define frailty; using other criteria to define frailty may affect the results. Finally, detailed driving statuses (e.g., frequency, driving under specific conditions such as at night and during bad weather) could not be considered in the analysis in this study due to limitations in the data. Further studies with sufficient cohort data and intervention studies should be conducted in the future.

In conclusion, frailty and driving status were found to be associated with the risk of disability. Not driving increased the risk of disability, particularly among frail older adults. The status of driving should be considered to assess the risk of disability.

ACKNOWLEDGMENT

We thank the Obu city and Takahama city office for help with participant recruitment.

CONTRIBUTORSHIP

TD: acquisition of the data, statistical analysis, interpretation of the data, and drafting of the manuscript. HS: study design and concept, and drafting and revising of the manuscript. IH and KT: acquisition of the data, statistical analysis, interpretation of the data, and drafting of the manuscript. NS and KS: acquisition and interpretation of the data and drafting of the manuscript.

COMPETING INTERESTS

None of the authors have any financial, personal, or potential conflict of interest with the material presented in this article.

DATA AVAILABILITY STATEMENT

No data are available.

FUNDING

This work was supported by AMED under grant number (15dk0207004h0203, 15dk0107003h0003); a Grant-in-Aid for Scientific Research (B) (grant number 23300205); the Funds of Obu City Local Government; and Research Funding for Longevity Sciences (26-33, 29-31, 30-7) from the National Center for Geriatrics and Gerontology, Japan.

REFERENCES

1 Collaborators. GDaH. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018;392:1859-922. doi: 10.1016/s0140-6736(18)32335-3

2 Fried LP, Tangen CM, Walston J, *et al.* Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001;56:M146-56. doi: 10.1093/gerona/56.3.M146

3 Hoogendijk EO, Afilalo J, Ensrud KE, *et al.* Frailty: implications for clinical practice and public health. *Lancet* 2019;394:1365-75. doi: 10.1016/s0140-6736(19)31786-6

4 Hirai H, Ichikawa M, Kondo N, *et al.* The risk of functional limitations after driving cessation among older Japanese adults: the JAGES cohort study. *J Epidemiol* 2019. doi: 10.2188/jea.JE20180260

5 Shimada H, Makizako H, Tsutsumimoto K, *et al.* Driving and incidence of functional limitation in older people: a prospective population-based study. *Gerontology* 2016;62:636-43. doi: 10.1159/000448036

6 National Police Agency. The white paper on police 2019.

7 Shimada H, Tsutsumimoto K, Lee S, *et al.* Driving continuity in cognitively impaired older drivers. *Geriatr Gerontol Int* 2016;16:508-14. doi: 10.1111/ggi.12504

8 Satake S, Shimada H, Yamada M, *et al.* Prevalence of frailty among community-dwellers and outpatients in Japan as defined by the Japanese version of the Cardiovascular Health Study criteria. *Geriatr Gerontol Int* 2017;17:2629-34. doi: 10.1111/ggi.13129

9 Shimada H, Makizako H, Doi T, *et al.* Incidence of disability in frail older persons with or without slow walking speed. *J Am Med Dir Assoc* 2015;16:690-6. doi:

10.1016/j.jamda.2015.03.019

10 Makizako H, Shimada H, Doi T, *et al.* Impact of physical frailty on disability in community-dwelling older adults: a prospective cohort study. *BMJ Open* 2015;5:e008462. doi: 10.1136/bmjopen-2015-008462

11 Fukutomi E, Okumiya K, Wada T, *et al.* Relationships between each category of 25-item frailty risk assessment (Kihon Checklist) and newly certified older adults under Long-Term Care Insurance: a 24-month follow-up study in a rural community in Japan. *Geriatr Gerontol Int* 2015;15:864-71. doi: 10.1111/ggi.12360

12 Chen LK, Liu LK, Woo J, *et al.* Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc* 2014;15:95-101. doi: 10.1016/j.jamda.2013.11.025

13 Tsutsui T, Muramatsu N. Japan's universal long-term care system reform of 2005: containing costs and realizing a vision. *J Am Geriatr Soc* 2007;55:1458-63. doi: 10.1111/j.1532-5415.2007.01281.x

14 Tsutsui T, Muramatsu N. Care-needs certification in the long-term care insurance system of Japan. *J Am Geriatr Soc* 2005;53:522-7. doi: 10.1111/j.1532-5415.2005.53175.x

15 Folstein MF, Folstein SE, McHugh PR. "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189-98. doi: 0022-3956(75)90026-6

16 Yesavage JA. Geriatric Depression Scale. *Psychopharmacol Bull* 1988;24:709-11. doi:

17 Shah RC, Maitra K, Barnes LL, *et al.* Relation of driving status to incident life space constriction in community-dwelling older persons: a prospective cohort study. *J Gerontol*

A Biol Sci Med Sci 2012;67:984-9. doi: 10.1093/gerona/gls133

18 Tsuji T, Rantakokko M, Portegijs E*, et al.* The effect of body mass index, lower extremity performance, and use of a private car on incident life-space restriction: a two-year follow-up study. *BMC Geriatr* 2018;18:271. doi: 10.1186/s12877-018-0956-3

19 Marie Dit Asse L, Fabrigoule C, Helmer C*, et al.* Automobile driving in older adults: factors affecting driving restriction in men and women. *J Am Geriatr Soc* 2014;62:2071-8. doi: 10.1111/jgs.13077

20 O'Connor ML, Edwards JD, Waters MP*, et al.* Mediators of the association between driving cessation and mortality among older adults. *J Aging Health* 2013;25:249s-69s. doi: 10.1177/0898264313497796

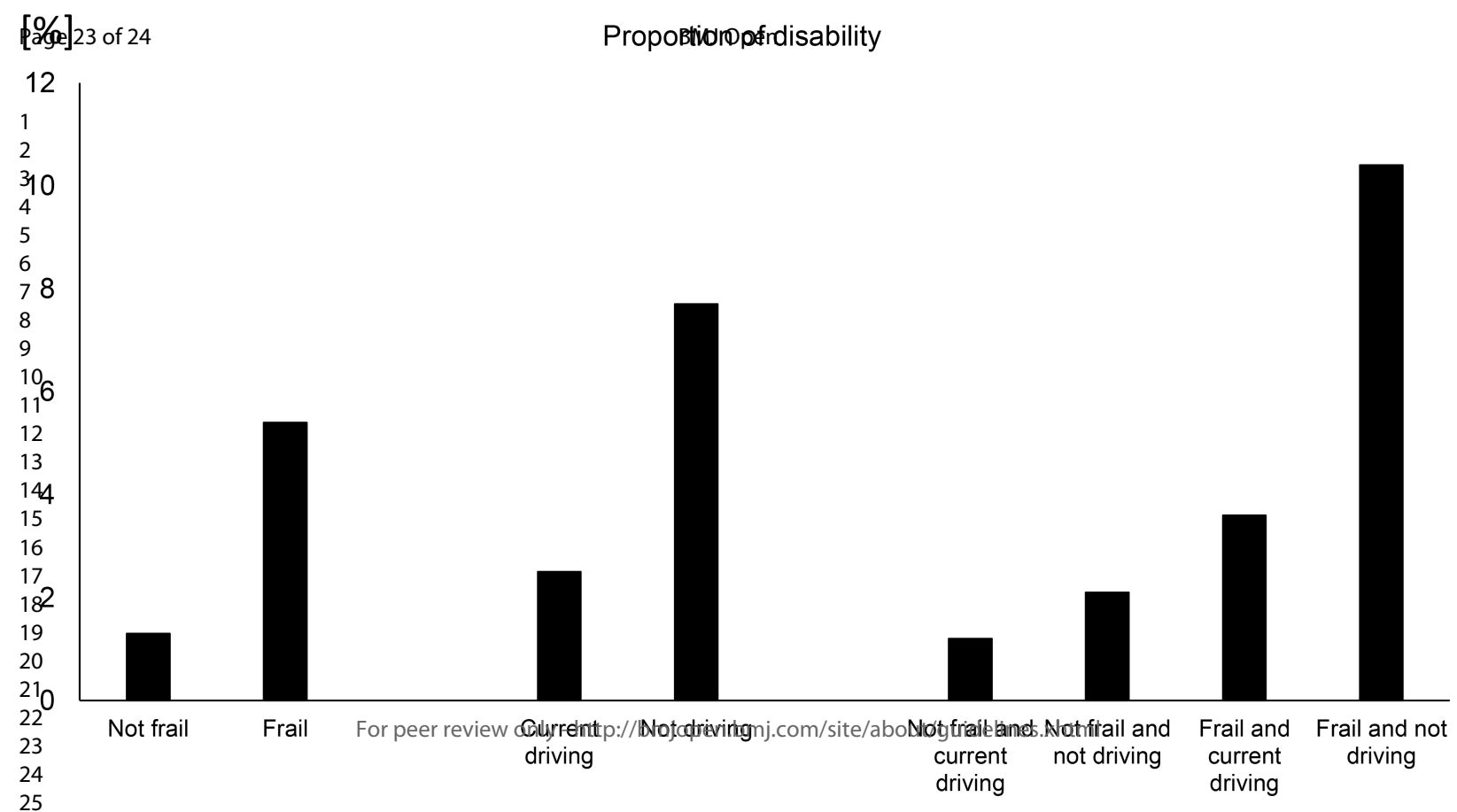
21 Edwards JD, Perkins M, Ross LA*, et al.* Driving status and three-year mortality among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* 2009;64:300-5. doi: 10.1093/gerona/gln019

22 Cabinet Office. White paper on traffic safety in Japan, 2016.

LEGENDS

Figure 1. Proportion of disability between frailty and driving statuses.

The definition of frail for classification into groups was pre-frailty or frailty.



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	9
		(*e*) Describe any sensitivity analyses	7-89
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-12
		(b) Give reasons for non-participation at each stage	9-12
		(c) Consider use of a flow diagram	9-12
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-12
		(b) Indicate number of participants with missing data for each variable of interest	9-12
		(c) Summarise follow-up time (eg, average and total amount)	9-12
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-12
		(*b*) Report category boundaries when continuous variables were categorized	9-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	9-12
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.