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Between person and within person associations of social interaction with physical frailty and subjective cognitive decline among community dwelling older adults in Japan

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Abstract

Introduction:

Social interaction, physical frailty, and subjective cognitive difficulties are important public health concerns in aging societies because they are relevant to community screening, health promotion, and preventive planning. This study examined whether longitudinal associations among social interaction (SI), Kihon Checklist-defined physical frailty (PF), and Kihon Checklist-defined subjective cognitive decline (SCD) mainly reflected stable between-person differences or within-person temporal processes among community-dwelling older adults.

Methods

This 6-year prospective cohort study used data from 307 adults aged 65 years and older in a Japanese community cohort in 2014, 2017, and 2020. SI was measured using the 18-item Index of Social Interaction. PF and SCD were operationalised using official Kihon Checklist domain-based cut-offs and treated as binary screening-defined states. A Bayesian random intercept cross-lagged panel model separated trait-like differences from within-person temporal deviations, adjusting for baseline covariates.

Results

Model fit was acceptable (PPP = 0.605; 95% CrI for the observed–replicated chi-square difference: -55.25 to 41.20; final PSR = 1.001). Higher trait-like SI was associated with lower trait-like PF (β = -0.445, 95% CrI − 0.649 to -0.230) and lower trait-like SCD (β = -0.354, 95% CrI − 0.636 to -0.065). Within-person autoregressive paths were observed, but all cross-lagged credible intervals included zero.

Conclusion

SI, PF, and SCD were associated mainly at the stable between-person level. Clear within-person cross-lagged associations were not observed; however, this finding should be interpreted cautiously because of the modest sample size, binary screening-defined outcomes, and limited temporal resolution. The findings support the use of social interaction as part of community-based functional aging profiles for population monitoring, early risk identification, and preventive public health planning, rather than as evidence of short-term temporal effects.

Introduction

Maintaining functional ability is a central goal of community health, health promotion, and aging research. In later life, physical frailty, cognitive decline, and social disconnection are all linked to reduced

independence, poorer quality of life, and greater care needs. [1–8] Social connectedness has also been associated with lower mortality, better cognitive outcomes, and healthier ageing trajectories. [6–15]

Social participation has been linked to lower frailty risk, reduced disability, and longer disability-free life expectancy, including in Japanese cohorts. [16–20] However, for gerontological interpretation and community-based ageing research, it remains unclear whether these associations indicate stable long-term risk profiles or short-term change processes. This distinction is important because the implications differ. If the associations are mainly between-person, social interaction may be useful for population monitoring, risk identification, and sustained community support. If the associations are mainly within-person, short-term changes in social interaction may be more directly relevant to preventing subsequent physical or cognitive decline. Most previous longitudinal studies have not explicitly separated these two levels of variation, which can lead to different interpretations of the same observed association. [21–23] This distinction is particularly relevant for community screening studies using KCL-defined risk states, because such indicators are often interpreted for long-term monitoring rather than clinical diagnosis. [28–32]

This study examined the longitudinal relationships among social interaction (SI), physical frailty (PF), and subjective cognitive decline (SCD) in community-dwelling older adults in Japan. SI was assessed using the Index of Social Interaction (ISI), which was developed in Japanese ageing research and has been linked to mortality, functional status, and broader social relationship patterns in later life. [24–27, 33] PF and SCD were operationalised using official domain-based cut-offs from the Kihon Checklist (KCL), consistent with Japanese community screening practice. [28–32]

The present study therefore aimed to clarify whether associations among SI, KCL-defined PF, and KCL-defined SCD in community-dwelling older adults are better understood as stable between-person functional aging profiles or as within-person temporal processes. This distinction is important for community health because conventional longitudinal associations may combine stable between-person differences with within-person temporal deviations, leading to different implications for population monitoring, early risk identification, health maintenance, and health promotion planning. [21–23] A Bayesian random intercept cross-lagged panel model was used to separate trait-like differences from within-person deviations across three waves. [21–23] We hypothesised that higher social interaction would be associated with lower physical frailty and lower subjective cognitive difficulty, while recognising that the available three-wave, 3-year interval data may be better suited to identifying stable community-level risk profiles than to establishing short-term temporal ordering. [6–20,24–27,33]

From a public health perspective, this distinction is not merely methodological. If social interaction is mainly linked with PF and SCD through stable between-person profiles, it may serve as a population-level marker for identifying older adults with less favorable functional aging profiles and for informing community-based health promotion strategies. [6–20,24–33] If, in contrast, short-term within-person changes are evident, the findings would have stronger implications for temporally targeted prevention.

[21–23] Clarifying this distinction may therefore help avoid overinterpreting conventional longitudinal associations and support more appropriate use of social, physical, and cognitive screening information in community public health practice. [21–23,28–32]

Methods

Study design and participants

This study was a 6-year longitudinal cohort study using data collected in 2014, 2017, and 2020 as part of the Community Empowerment and Care for Well-being and Healthy Longevity study in a suburban area of Japan. The target population consisted of community-dwelling adults aged 65 years and older at baseline in 2014. The analytic sample included participants who had valid scores or valid classifications for the three main variables at all three waves. The final analytic sample comprised 307 participants.

The study population consisted of community-dwelling older adults who were able to participate in the survey. Individuals who were institutionalised, receiving full-time nursing care, or unable to provide meaningful survey responses were not included in the source cohort. Invalid wave scores were defined as missing 9 or more items for the 18-item ISI, missing 2 or more items for the 5-item KCL physical domain, or missing 2 or more items for the 3-item KCL cognitive domain. Participants with invalid or missing data for any of the three primary variables at any wave were not included in the analytic sample. Although this approach improved interpretability of the longitudinal model by ensuring valid repeated measurement of all three focal constructs, it may also have increased vulnerability to selection bias related to attrition and missingness, particularly if participants retained in the analytic sample were healthier, more stable, or more likely to remain engaged over time. [37, 38] Accordingly, the present findings should be interpreted as characterising associations among older adults with valid repeated measurement across all three focal constructs over the 6-year follow-up.

Participant selection is shown in Fig. 1.

Measures

Social interaction

Social interaction was measured using the ISI, an 18-item multidimensional instrument developed for older adults in Japan. [24–27] The scale covers five domains: independence, social curiosity, interaction, participation in society, and feelings of safety. Higher total scores indicate greater social interaction.

Physical frailty

Physical frailty was assessed using the physical function domain of the KCL, comprising items Q6-Q10. [28–30] Rather than using a positively scored continuous summary, the domain was classified according to the official KCL domain-based cut-off. Participants with 3 or more unfavourable responses were classified as positive for physical frailty. [28–30]

Subjective cognitive decline

Subjective cognitive decline was operationalised using the cognitive function domain of the Kihon Checklist (items Q18-Q20). Participants with one or more unfavourable responses were classified as positive for SCD. [28, 30–32] In the present study, this variable was treated as a KCL-based community screening indicator of subjective cognitive difficulty rather than as a syndrome-level clinical diagnosis. This operationalisation was considered appropriate for three reasons. First, the KCL cognitive domain consists of self-reported cognitive complaints and cognitively oriented daily function items, which makes it suitable as a community screening indicator of subjective cognitive difficulty. Second, previous Japanese studies have directly used the KCL cognitive function domain to assess subjective cognitive decline or closely related subjective cognitive complaints in community-dwelling older adults. Third, the KCL cognitive function domain has shown predictive validity for later dementia in population-based follow-up, supporting its relevance as an early-risk screening construct in community settings, while not equating it with clinically adjudicated cognitive impairment. [31, 32, 34, 35]

Covariates

Baseline covariates included age, sex, employment status, subjective economic status, smoking status, alcohol consumption, and chronic disease count. Age and chronic disease count were treated as continuous variables. Sex was coded as 1 = male and 2 = female. Employment status was coded as 0 = not working and 1 = working. Subjective economic status was coded as 0 = not good and 1 = good. Smoking status was coded as 0 = non-smoker and 1 = current smoker. Alcohol consumption was coded as 0 = non-drinker and 1 = current drinker.

Statistical analysis

To address the longitudinal question while separating stable person-level differences from within-person temporal deviations, a Bayesian RI-CLPM was estimated. [21–23] SI was modelled as a repeated continuous variable across the three waves. PF and SCD were modelled as repeated binary states. The model estimated associations among random intercepts, autoregressive paths within each construct, and cross-lagged paths across constructs.

Baseline covariates were specified as predictors of the random intercepts only, so that covariate adjustment was applied at the trait level rather than to wave-specific deviations. [23] To retain the analytic sample, baseline covariates with missing values were included in the model by estimating their means and variances within the Bayesian framework, rather than treating them as fixed exogenous variables.

Bayesian estimation was conducted in Mplus version 8.3. [40] Model fit was evaluated using the posterior predictive p-value, the 95% credible interval for the difference between observed and replicated chi-square values, and the potential scale reduction factor. Interpretation followed current recommendations for Bayesian reporting. [39]

The conceptual RI-CLPM is shown in Fig. 2.

Results

Baseline characteristics of the study sample are presented in Table 1. The analytic sample included 307 community-dwelling older adults. The mean baseline age was 71.64 years (SD = 5.61), and the mean chronic disease count was 1.36 (SD = 1.04). Mean social interaction scores declined across waves, from 16.82 (SD = 1.75) in 2014 to 16.52 (SD = 2.03) in 2017 and 16.09 (SD = 2.44) in 2020. The prevalence of physical frailty increased from 8.8% in 2014 to 12.4% in 2017 and 19.5% in 2020. Subjective cognitive decline was present in 31.3% of participants in 2014, 59.9% in 2017, and 62.9% in 2020.

Table 1. Characteristics of the study sample (n = 307)

Panel A. Continuous variables

Variable	Mean ± SD
Baseline age	71.64 ± 5.61
Chronic disease count	1.36 ± 1.04
Social interaction T1 (2014)	16.82 ± 1.75
Social interaction T2 (2017)	16.52 ± 2.03
Social interaction T3 (2020)	16.09 ± 2.44

Panel B. Categorical covariates and binary outcomes

Variable	Category	n (%)
Sex	Male	139 (45.3)
	Female	168 (54.7)
Employment status	Working	142 (46.3)
	Not working	131 (42.7)
	Missing	34 (11.1)
Subjective economic status	Good	246 (80.1)
	Not good	49 (16.0)
	Missing	12 (3.9)
Smoking status	Current smoker	27 (8.8)
	Non-smoker	265 (86.3)
	Missing	15 (4.9)
Alcohol consumption	Current drinker	109 (35.5)
	Non-drinker	191 (62.2)
	Missing	7 (2.3)
Physical frailty at T1 (2014)	Present	27 (8.8)
	Not present	280 (91.2)
Physical frailty at T2 (2017)	Present	38 (12.4)
	Not present	269 (87.6)
Physical frailty at T3 (2020)	Present	60 (19.5)
	Not present	247 (80.5)
Subjective cognitive decline at T1 (2014)	Present	96 (31.3)
	Not present	211 (68.7)
Subjective cognitive decline at T2 (2017)	Present	184 (59.9)
	Not present	123 (40.1)
Subjective cognitive decline at T3 (2020)	Present	193 (62.9)
	Not present	114 (37.1)

Note: Data are presented as mean ± standard deviation (SD) for continuous variables and n (%) for categorical variables. Social interaction was assessed using the 18-item Index of Social Interaction.

Physical frailty and subjective cognitive decline were operationalised using the physical and cognitive domains of the Kihon Checklist, respectively, based on official domain-based cut-offs. Percentages for baseline categorical covariates were calculated using the full analytic sample (n = 307), with missing values shown explicitly where applicable.

Abbreviations: SD, standard deviation; T1, baseline in 2014; T2, 2017 follow-up; T3, 2020 follow-up.

Model fit, between-person associations, and trait-level covariate effects are shown in Table 2. The Bayesian RI-CLPM showed acceptable global fit, with a posterior predictive p-value of 0.605 and a 95% credible interval for the difference between observed and replicated chi-square values ranging from -55.25 to 41.20. Convergence was satisfactory, with a final potential scale reduction factor of 1.001.

At the between-person level, higher stable social interaction was associated with lower stable physical frailty and lower stable subjective cognitive decline. The standardised association between the random intercepts of SI and PF was β = -0.445 (95% CrI, -0.649 to -0.230), and that between SI and SCD was β = -0.354 (95% CrI, -0.636 to -0.065). The association between trait-level PF and trait-level SCD was positive in direction but uncertain (β = 0.270, 95% CrI, -0.044 to 0.565).

Among baseline covariates, older age was associated with lower trait-level SI, higher trait-level PF, and higher trait-level SCD. Employment was positively associated with trait-level SI. Chronic disease count was positively associated with trait-level PF and showed a positive tendency for trait-level SCD. The remaining baseline covariates showed no clear associations with the random intercepts.

Table 2. Bayesian model fit, between-person associations, and trait-level covariate effects in the RI-CLPM

Panel A. Model fit and convergence diagnostics

Index	Value
Number of observations	307
Estimator	Bayesian estimation
Link function	Probit
Number of chains	4
Iterations	320,000
Thinning	10
Number of free parameters	119
Posterior predictive p-value (PPP)	0.605
95% CrI for observed–replicated χ^2 difference	-55.25 to 41.20
Final PSR	1.001

Panel B. Between-person associations among random intercepts

Path	Standardized β	95% CrI
RI-SI with RI-PF	-0.445	-0.649 to -0.230
RI-SI with RI-SCD	-0.354	-0.636 to -0.065
RI-PF with RI-SCD	0.270	-0.044 to 0.565

Panel C. Trait-level covariate effects on random intercepts

Covariate	RI-SI β (95% CrI)	RI-PF β (95% CrI)	RI-SCD β (95% CrI)
Age	-0.339 (-0.553 to -0.117)	0.509 (0.340 to 0.665)	0.336 (0.015 to 0.619)
Sex	0.042 (-0.107 to 0.210)	0.042 (-0.115 to 0.201)	0.040 (-0.176 to 0.254)
Employment status	0.243 (0.080 to 0.412)	-0.100 (-0.264 to 0.066)	0.116 (-0.101 to 0.334)
Subjective economic status	0.046 (-0.098 to 0.194)	-0.133 (-0.264 to 0.003)	-0.124 (-0.311 to 0.065)
Smoking status	-0.133 (-0.287 to 0.019)	-0.037 (-0.202 to 0.121)	0.076 (-0.109 to 0.265)
Alcohol consumption	0.018 (-0.152 to 0.184)	-0.038 (-0.207 to 0.131)	-0.110 (-0.323 to 0.111)
Chronic disease count	-0.036 (-0.238 to 0.165)	0.188 (0.007 to 0.360)	0.228 (-0.043 to 0.501)

Note: Panel A presents Bayesian model fit and convergence diagnostics. Panel B presents standardized between-person associations among the random intercepts of social interaction (SI), physical frailty (PF), and subjective cognitive decline (SCD). Panel C presents standardized effects of baseline covariates on the random intercepts. Covariates were specified as predictors of the trait-level components only. Estimates are reported as standardized coefficients with 95% credible intervals (CrIs).

Abbreviations: RI-CLPM, random intercept cross-lagged panel model; RI, random intercept; SI, social interaction; PF, physical frailty; SCD, subjective cognitive decline; PPP, posterior predictive p-value; PSR, potential scale reduction factor; CrI, credible interval.

Within-person autoregressive and cross-lagged estimates are presented in Table 3. All three constructs showed autoregressive continuity across waves. For SI, the autoregressive effects were β = 0.317 (95% CrI, 0.077 to 0.520) from 2014 to 2017 and β = 0.320 (95% CrI, 0.061 to 0.555) from 2017 to 2020. For PF, the corresponding effects were β = 0.302 (95% CrI, 0.012 to 0.723) and β = 0.505 (95% CrI, 0.017 to 0.895). For SCD, they were β = 0.332 (95% CrI, 0.076 to 0.749) and β = 0.601 (95% CrI, 0.135 to 0.927).

Cross-lagged effects were generally small and all 95% credible intervals included zero. A directionally coherent pattern was observed for the SI-PF pair. For the SI-PF pair, the point estimates were negative in both directions across the two intervals. Paths involving SCD were close to zero throughout. Taken together, these findings indicate that the clearest evidence in the present model was observed at the between-person level, whereas the within-person cross-lagged estimates remained uncertain under the present data structure.

Table 3. Standardized within-person autoregressive and cross-lagged effects across the 2014–2017 and 2017–2020 intervals

Panel A. Autoregressive effects

Path	Standardized β	95% CrI
SI T1 → SI T2	0.317	0.077 to 0.520
SI T2 → SI T3	0.320	0.061 to 0.555
PF T1 → PF T2	0.302	0.012 to 0.723
PF T2 → PF T3	0.505	0.017 to 0.895
SCD T1 → SCD T2	0.332	0.076 to 0.749
SCD T2 → SCD T3	0.601	0.135 to 0.927

Panel B. Cross-lagged effects

Path	Standardized β	95% CrI
PF T1 → SI T2	-0.077	-0.334 to 0.188
PF T2 → SI T3	-0.111	-0.475 to 0.224
SCD T1 → SI T2	0.028	-0.224 to 0.282
SCD T2 → SI T3	0.047	-0.312 to 0.374
SI T1 → PF T2	-0.060	-0.378 to 0.295
SI T2 → PF T3	-0.069	-0.389 to 0.299
SCD T1 → PF T2	-0.002	-0.352 to 0.317
SCD T2 → PF T3	-0.004	-0.503 to 0.499
SI T1 → SCD T2	0.013	-0.272 to 0.326
SI T2 → SCD T3	0.014	-0.293 to 0.315
PF T1 → SCD T2	0.001	-0.303 to 0.283
PF T2 → SCD T3	0.001	-0.405 to 0.432

Note: Panel A presents autoregressive effects, indicating the extent to which deviations from an individual's expected level persisted to the next wave within the same construct. Panel B presents cross-lagged effects, indicating whether deviations in one construct predicted subsequent deviations in another construct. Estimates are standardized coefficients with 95% credible intervals (CrIs). All paths were estimated within the Bayesian RI-CLPM while controlling for stable between-person differences through random intercepts.

Abbreviations: SI, social interaction; PF, physical frailty; SCD, subjective cognitive decline; T1, 2014; T2, 2017; T3, 2020; CrI, credible interval.

Discussion

The principal finding of this study was that social interaction, KCL-defined physical frailty, and KCL-defined subjective cognitive difficulty were more clearly linked at the stable between-person level than at the within-person cross-lagged level. Older adults with consistently higher social interaction tended to show a more favorable functional aging profile, characterized by lower screening-defined physical frailty and lower screening-defined subjective cognitive difficulty. This finding is consistent with prior evidence linking stronger social relationships and social participation with healthier aging, lower frailty risk, reduced functional disability, and better cognitive outcomes. [6-20,24-27,33] In contrast, clear within-person cross-lagged associations were not observed across the 3-year intervals. This pattern should not be interpreted as evidence that within-person processes are absent. Rather, given the modest sample size, binary screening-defined outcomes, and three-wave design with relatively long intervals, the findings indicate that the present data were better suited to identifying stable community-level risk profiles than to establishing short-term temporal ordering among the three domains. [21-23,28-32]

From a public health perspective, these findings support a profile-based interpretation of social interaction in later life. Rather than suggesting that short-term changes in social interaction directly produce subsequent changes in frailty or subjective cognitive difficulty, the results indicate that social interaction may help characterize older adults with more favorable or more vulnerable functional aging profiles. [6-20,24-33] This interpretation is relevant to community-based screening, health promotion, and preventive planning because social participation, physical functioning, and subjective cognitive difficulties are observable and potentially monitorable domains in community-dwelling populations. [16-20,28-33] Social interaction may therefore be considered one component of population-level functional aging assessment, particularly in settings where community health workers, local governments, or preventive care programs seek to identify groups who may benefit from sustained social and functional support. [6-20,24-33] Further evidence is needed before drawing conclusions about temporal ordering, individual-level causal pathways, or short-term intervention effects. [21-23]

Taken together, these findings support a cautious profile-based interpretation of social interaction in this cohort. Social interaction was clearly linked with screening-defined physical frailty and subjective cognitive difficulty at the stable between-person level, whereas the present data did not provide clear evidence for short-term cross-domain temporal ordering. This interpretation is compatible with broader aging frameworks that view physical, cognitive, and social resources as accumulated and maintained over time [1-8] , and with cohort evidence linking social connectedness, social participation, and social relationship patterns with mortality, dementia risk, frailty, disability, and functional status in later life. [6-20,24-27,33]

The SI-PF relationship deserves cautious attention. Although all cross-lagged credible intervals included zero, the estimated directions were consistent across both intervals: higher SI tended to predict lower later PF, and higher PF tended to predict lower later SI. This pattern should not be interpreted as evidence of a confirmed reciprocal mechanism. Instead, it should be treated as hypothesis-generating evidence that the SI-PF link may warrant further testing in cohorts with larger samples, shorter intervals, more measurement occasions, and richer measures of physical functioning. This cautious interpretation is consistent with previous longitudinal evidence linking social participation with lower frailty risk, prevention of functional disability, and longer disability-free life expectancy in older adults. [16-20]

Paths involving SCD were close to zero at the within-person level. This may partly reflect the nature of the measure: the KCL cognitive domain is a community screening indicator of subjective cognitive difficulty, not a clinically adjudicated diagnosis of SCD or preclinical Alzheimer's disease. Previous studies nevertheless support the relevance of KCL cognitive items to subjective cognitive complaints and later dementia risk, and broader SCD literature suggests that subjective cognitive decline is a heterogeneous construct whose prognostic meaning depends on measurement context and population characteristics. [31,32,34-36] In this cohort, KCL-based subjective cognitive difficulty was more clearly represented in stable between-person profiles than in short-interval within-person cross-lagged paths; however, this should be interpreted cautiously given the screening-based nature of the measure and the heterogeneity of SCD constructs. [31,32,34-36]

A key strength of this study is that it clarifies the level at which SI-PF-SCD associations are most evident, which is directly relevant to how longitudinal findings should be interpreted in public health research. [21-23] By separating stable between-person differences from within-person temporal deviations, the study reduces the risk of interpreting population-level associations as short-term individual-level temporal processes. [21-23] In addition, the use of official KCL domain-based thresholds improved alignment with Japanese community screening practice and made PF and SCD interpretable as screening-defined geriatric risk states. [28-32] This design is particularly relevant for community health research because social interaction, physical frailty, and subjective cognitive difficulty are commonly observed in community-dwelling older adults and may jointly inform population monitoring and preventive planning. [6-20,24-33]

Limitations

Several limitations should be considered. First, the study included only three waves with 3-year intervals, which may have been too coarse to detect shorter-term within-person changes in social interaction, frailty status, or subjective cognitive difficulty. Second, PF and SCD were based on questionnaire-derived KCL domains rather than clinical diagnoses or objective performance testing; therefore, the findings should be interpreted as relating to screening-based states in community settings rather than clinical syndromes. [28-36] In particular, the SCD measure in this study reflects a KCL-based community screening

indicator and should not be treated as equivalent to a full syndrome-level or clinically adjudicated definition of subjective cognitive decline.

A further limitation is that the absence of credible within-person cross-lagged associations should not be interpreted as evidence against meaningful within-person processes. The analytic conditions in the present study were not optimal for detecting such processes: the sample size was modest, PF and SCD were modelled as binary screening-defined states, and only three measurement occasions separated by 3-year intervals were available. These features may have reduced statistical power and temporal resolution, particularly for detecting small or short-lived changes in social interaction, frailty status, or subjective cognitive difficulty. [21-23,28-32] Therefore, the within-person findings should be considered inconclusive rather than definitively null.

Third, the analytic sample was restricted to participants with valid data on all three focal variables across all three waves. Although this improved interpretability of the longitudinal model, it may also have introduced selection bias. In particular, this restriction may have favoured individuals who were healthier, more stable, or more likely to remain engaged over time, while under-representing participants with greater frailty, greater cognitive vulnerability, or more disrupted response patterns. As a result, the observed dominance of between-person associations may have been strengthened to some extent by selective retention. Future studies using larger samples, shorter follow-up intervals, and less restrictive missing-data strategies are needed to examine whether weaker within-person processes may have been underestimated in the present complete-case analytic sample. [37,38]

Fourth, the study was conducted in a suburban Japanese setting, so external generalisability to other populations and service contexts should be made cautiously. Finally, residual confounding remains possible because factors such as education, depressive symptoms, and objective cognitive performance were not modelled in the present analysis. Accordingly, the findings should not be used to infer the effectiveness of specific community interventions or policy programs. They are better interpreted as epidemiological evidence on how social, physical, and cognitive screening indicators cluster over time in a community-dwelling older population. [21-23,28-32] Future studies incorporating objective physical performance, standardized cognitive assessment, depressive symptoms, and more frequent repeated measurements are needed to clarify whether social interaction is involved in shorter-term temporal processes or primarily reflects stable functional aging profiles. [21-23,34-36]

Conclusion

In this 6-year cohort of community-dwelling older adults in Japan, social interaction, KCL-defined physical frailty, and KCL-defined subjective cognitive difficulty were associated mainly at the stable between-person level. Older adults with consistently higher social interaction tended to show lower screening-defined physical frailty and lower screening-defined subjective cognitive difficulty. [6-20,24-33] Clear within-person cross-lagged associations were not observed, but this finding should be interpreted cautiously because of the modest sample size, binary outcomes, and limited temporal resolution. [21-

[23,28-32] The results support the use of social interaction as part of community-level functional aging profiles for population monitoring, early risk identification, and preventive public health planning, while further studies with larger samples, more waves, shorter intervals, and richer clinical measures are needed to clarify temporal processes among social, physical, and cognitive domains. [6-20,24-36]

Declarations

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Author contributions

Study conception and design: Haotian Gao, Ruifeng Zhao, Shuanghong Li, Tokie Anme. Data collection: all authors. Data analysis and interpretation: Haotian Gao, Ruifeng Zhao, Shuanghong Li. Drafting of the manuscript: Haotian Gao. Critical revision of the manuscript: Tokie Anme, Shuanghong Li. All authors approved the final version of the manuscript.

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Conflict of interest

Haotian Gao received financial support from the Japan China Sasakawa Medical Fellowship through the Japan China Medical Association. The authors declare no other conflict of interest.

Data availability statement

The datasets generated during and/or analysed during the current study are not publicly available due to the confidentiality of community survey data and research governance restrictions but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the University of Tsukuba, Japan (approval No. 1331-7). Participation in the original community surveys was voluntary and return of the completed questionnaire after provision of the survey information was regarded as informed consent to participate in the original survey procedures. The present study used anonymized existing data provided under a collaborative research framework between T village and the University of Tsukuba. According to the approved ethics documents, the use of these data for the present secondary analysis was based on

procedures at the source institution, including public disclosure of the research information on the municipal website and disclosure of procedures for requesting discontinuation of data use or provision. All procedures involving human participants and human data were conducted in accordance with relevant guidelines and regulations, including the Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to publish

Not applicable.

Clinical trial number

Not applicable.

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Figures

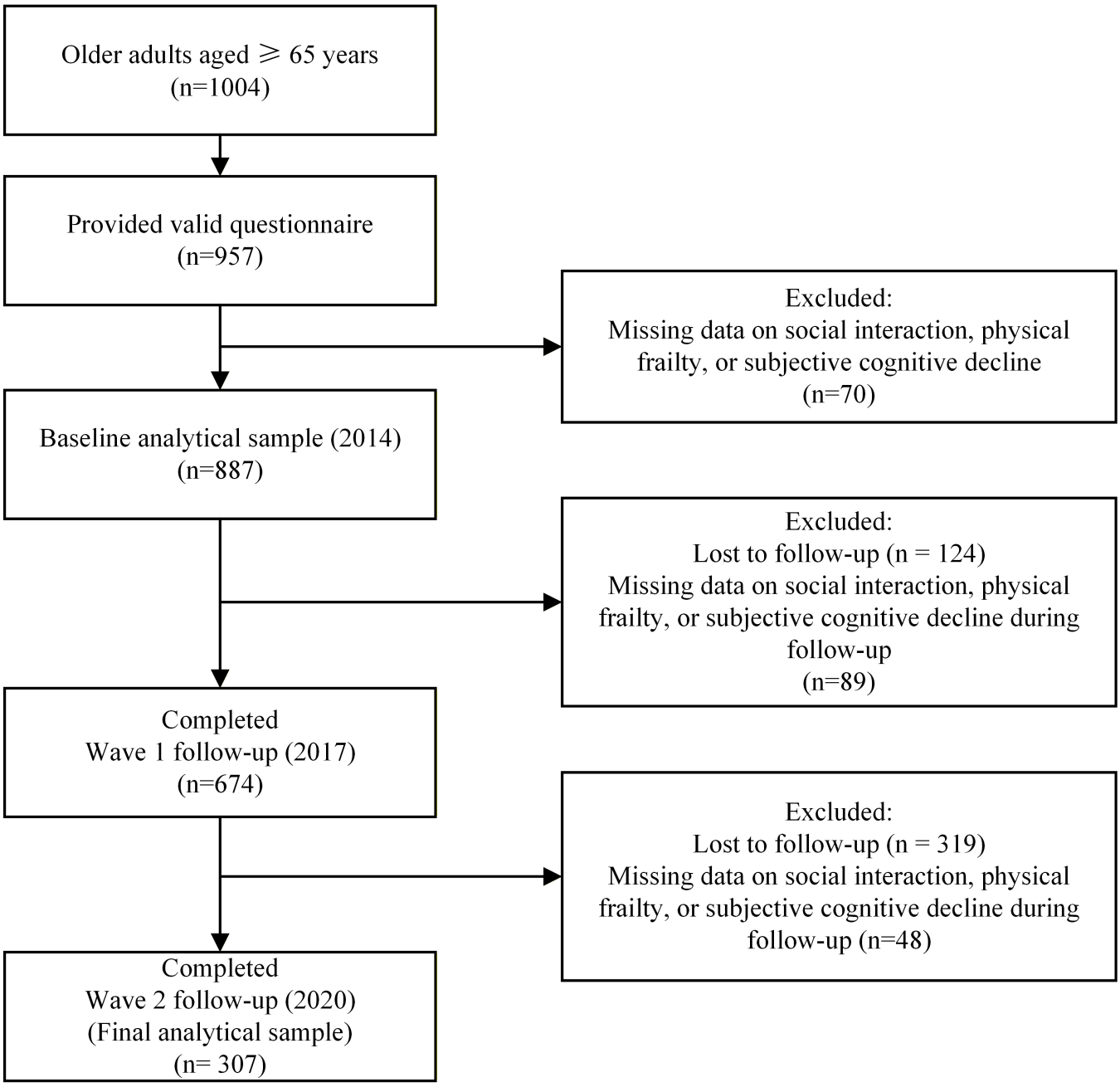


Figure 1

Flowchart of participant selection across the 2014, 2017, and 2020 survey waves

Note: The source population comprised community-dwelling older adults aged 65 years and over at baseline in 2014. Participants were excluded if they were institutionalised, receiving full-time nursing care, or had conditions preventing meaningful participation. Invalid wave scores were defined as missing ≥9 items for the 18-item Index of Social Interaction (ISI), missing ≥2 items for the 5-item Kihon Checklist (KCL) physical domain, or missing ≥2 items for the 3-item KCL cognitive domain. Participants with invalid or missing classifications for any of the three focal variables at any wave were excluded from the analytic sample. Final analytic sample: n = 307.

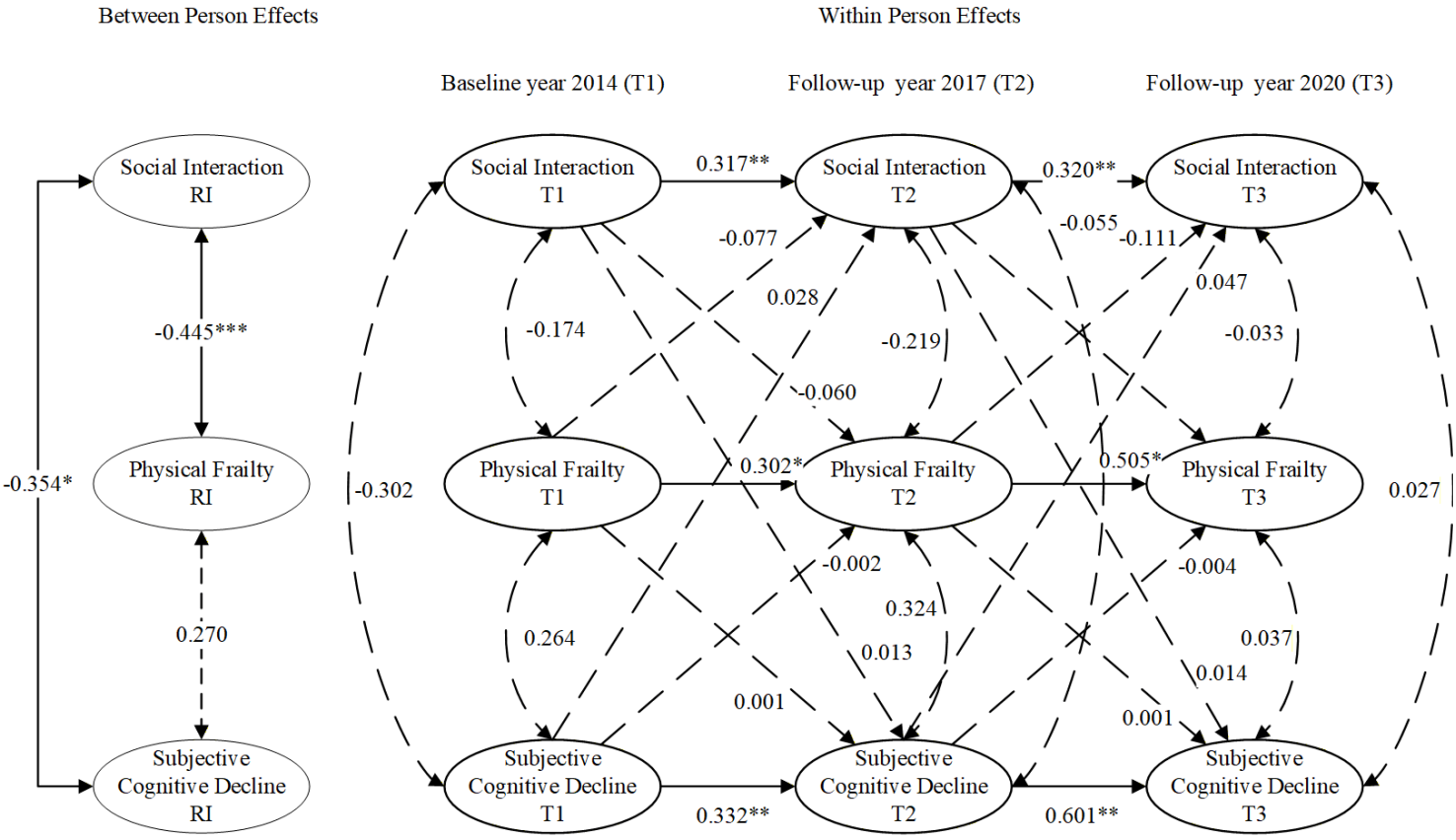


Figure 2

Conceptual path diagram of the Bayesian random intercept cross-lagged panel model

Note: SI was modelled as a continuous repeated measure using the Index of Social Interaction. PF and SCD were modelled as binary repeated states using the physical and cognitive domains of the Kihon Checklist, respectively. Random intercepts represent stable between-person differences. Within-person latent components represent deviations from an individual's expected level at each wave. Autoregressive paths indicate temporal carry-over within the same construct, and cross-lagged paths indicate prospective within-person associations across constructs. Baseline covariates were specified as predictors of the random intercepts only. For visual clarity, residual correlations among within-wave latent deviations and thresholds/intercepts are not fully displayed. RI denotes random intercepts. Displayed coefficients are standardized; solid lines indicate p < .05 (* p < .05, ** p < .01, *** p < .001). Covariate paths to random intercepts are omitted for clarity.

Abbreviations: RI-CLPM, random intercept cross-lagged panel model; SI, social interaction; PF, physical frailty; SCD, subjective cognitive decline.