

Arthritis and Risk of Falls, Hospitalization, and Out-of-Pocket Medical Spending Among Middle-Aged and Older Chinese Adults: A Time-Dependent Cox Analysis of the CHARLS Cohort, 2011-2020

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Abstract

Background.

Arthritis affects one in three Chinese adults aged 45 years and older and is a leading cause of functional decline. Whether arthritis independently predicts downstream adverse events (falls, hospitalization, and out-of-pocket [OOP] medical spending) over the long term, and whether prevalent and incident arthritis carry different risks, remains incompletely characterized.

Methods.

We analyzed five waves (2011, 2013, 2015, 2018, 2020) of the China Health and Retirement Longitudinal Study (CHARLS). Adults aged 45 years and older free of falls or overnight hospitalization at baseline were followed. Arthritis status was carried forward across waves and treated as a time-varying exposure. Falls (Waves 2–4) and overnight hospitalization (Waves 2–5) were modeled with time-dependent Cox regression; OOP spending was modeled with pooled logistic and two-part GEE. Three nested models adjusted for age, sex, residence, education (Model 2), and additionally for BMI, depression, smoking, drinking, comorbidity count, and ADL disability (Model 3). Pre-specified analyses stratified by sex, separated prevalent versus incident arthritis, applied a one-wave-lagged exposure, and addressed attrition bias.

Results.

Among 10,515 fall-cohort participants (Model 3, 25,045 person-intervals, 56,978 person-years, 3,349 incident falls), arthritis was associated with a 42% higher fall risk (HR 1.42, 95% CI 1.32–1.52; $P = 1.3 \times 10^{-23}$). In 11,507 hospitalization-cohort participants (34,399 intervals, 76,634 person-years, 4,416 hospitalizations), the HR was 1.18 (1.11–1.25; $P = 5.5 \times 10^{-8}$). In repeated-interval GEE on 12,532 persons, arthritis was associated with any OOP spending (OR 1.33, 95% CI 1.25–1.42; $P = 4.2 \times 10^{-19}$; absolute rates 29.5% vs 21.4%) but not with the amount of spending among spenders. Both prevalent (HR 1.44) and incident (HR 1.23) arthritis predicted falls; associations were consistent across sex (interaction $P = 0.25$), were unchanged under a one-wave exposure lag (HR 1.38), and persisted after excluding early dropouts. Cognitive decline (≥ 3 -point, ≥ 1 -SD, memory, or executive) and hip fracture yielded complementary patterns: hip fracture HR 1.20 (1.05–1.37), but all four cognitive-decline definitions were null (HR approximately 1.00).

Conclusions.

Arthritis, whether prevalent or incident, is an independent, persistent predictor of falls, hospitalization, and increased likelihood of any OOP medical spending in Chinese middle-aged and older adults. The

absence of an arthritis-cognitive-decline association argues against a strong causal pathway. Findings support integrating fall-prevention, comorbidity management, and financial-protection strategies into routine arthritis care.

Background

Musculoskeletal disorders, of which arthritis is the most prevalent, ranked as the second-leading cause of years lived with disability in China in 2021 [1]. Among Chinese adults aged 45 years and older, the self-reported prevalence of arthritis in CHARLS exceeds 30% [2], and projections based on the Global Burden of Disease Study 2019 indicate that the osteoarthritis burden in China will continue to rise through 2039 [3]. Beyond joint pain, arthritis contributes to sarcopenia, balance impairment, and reduced mobility, all established risk factors for falls in older adults [4]. Each year, roughly one in three community-dwelling adults aged 65 years and older experiences a fall, and falls account for more than half of unintentional-injury deaths in China [5]. Hospitalization rates among middle-aged and older Chinese have been rising with the dual burden of chronic disease, and out-of-pocket (OOP) payments remain a leading cause of catastrophic health expenditure in households with chronic-disease members [6].

Despite these connections, three questions remain open. First, most prior studies treat arthritis exposure as a single, fixed baseline value; whether its association with downstream events strengthens, weakens, or persists as arthritis accumulates or newly develops during follow-up remains understudied. Second, while individual studies have linked arthritis to falls, hospitalization, or economic burden, no single longitudinal cohort in China has jointly quantified the three outcomes against the same time-updated exposure. Third, prior CHARLS analyses of arthritis and falls have been limited to single time-anchored designs (cross-sectional, PSM-matched, or non-time-varying Cox) [7–9], precluding causal inference about the temporal sequence of exposure and outcome.

We addressed these gaps using five CHARLS waves (2011–2020). Treating self-reported arthritis as a time-varying exposure carried forward across waves, we estimated associations with incident falls, incident overnight hospitalization, and OOP medical spending. We further distinguished prevalent and incident arthritis, applied a one-wave-lagged sensitivity analysis to test for reverse causation, and used four operationalizations of cognitive decline plus hip fracture as contrasting outcomes to triangulate the specificity of the arthritis effect.

Methods

Data source and study population

CHARLS is a nationally representative biennial-to-triennial survey of Chinese adults aged 45 years and older, with baseline in 2011 (Wave 1) and follow-up waves in 2013, 2015, 2018, and 2020 [10]. The present analysis used all five waves. Two analytic cohorts were constructed. (i) The falls cohort excluded Wave-1 participants with a self-reported fall in the past two years, missing fall status, or

missing baseline arthritis status, yielding 13,661 participants for Models 1–2 and 10,515 for Model 3 (after additionally requiring complete covariates). (ii) The hospitalization cohort excluded Wave-1 participants with overnight hospitalization in the past year, missing hospitalization status, or missing arthritis, yielding 15,801 for Models 1–2 and 11,507 for Model 3. The OOP cohort comprised 12,532 Wave-1 participants with non-missing exposure, outcome, and covariates. The cohort flow is shown in Fig. 1.

Exposure: time-varying arthritis

Self-reported doctor-diagnosed arthritis was obtained at each wave. For each person-interval we used the most recent observed value carried forward (last-observation-carried-forward), avoiding look-ahead. A person-level exposure history was derived: prevalent if arthritis was reported at Wave 1; incident if first reported at Wave 2 or later; never otherwise. For sensitivity analyses the exposure was decomposed into two time-varying indicators: prevalent (constant 1) and incident (1 only from the wave of first report onward). For the lag-1 sensitivity analysis we used the arthritis status one wave earlier than the interval start.

Outcomes

Falls. Self-reported any fall in the two years preceding each wave, available in Waves 1–4. The Wave-1 value defines the baseline exclusion; the Wave-2/3/4 values are the interval-level events.

Overnight hospitalization. Self-reported any overnight hospital stay in the past year, available in all five waves.

Out-of-pocket medical spending. Total annual OOP was derived as oophos1y (past-year inpatient OOP) plus $12 \times \text{oopdoc1m}$ (past-month outpatient OOP annualized), consistent with prior CHARLS studies. A binary indicator any OOP was the primary economic outcome; among spenders, $\log(\text{OOP} + 1)$ was modeled for amount.

Cognitive decline. Total cognition score (0–21). The decline event was a drop of ≥ 3 points from the prior wave in the main analysis; three additional definitions were used in robustness checks: ≥ 1 sample-SD drop in total cognition, and ≥ 2 -point drops in memory or executive domains.

Hip fracture / hip problem. Binary variable hip at Waves 1–5.

Covariates

Baseline (Wave-1) covariates: age (continuous, time-updated in survival models), sex (male/female), rural residence, education (elementary or below, junior high, senior high, college or above), body mass index (10–60 kg/m² range, baseline-anchored because later waves have heavy BMI missingness),

depression (CESD-10 ≥ 10 , a validated cut-point for clinically significant depressive symptoms [11]), ever-smoker, ever-drinker, comorbidity count (hypertension, diabetes, heart disease, stroke, lung disease, cancer), and ADL disability (any difficulty in activities of daily living).

Statistical analysis

For falls and hospitalization, we used time-dependent Cox regression, in which covariates measured at the start of each interval predict events occurring within it [12] (CoxTimeVaryingFitter in Python lifelines 0.30, with L2 penalizer 0.01). Each person-interval was a row defined by (start, stop) at wave years, with the carry-forward exposure at start and the event at stop. After a fall or hospitalization a person was removed from further contribution (first-event). Three nested models: Model 1 (exposure only); Model 2 (+ age, sex, rural, education); Model 3 (+ BMI, depression, smoking, drinking, comorbidity, ADL). Schoenfeld residual tests were used to check the proportional hazards assumption.

For OOP, guided by the Andersen behavioral model of health-services use [13], we fitted a pooled logistic GEE (independence working correlation, cluster-robust SEs by participant) for any OOP per interval and a Gaussian GEE for $\log(\text{OOP} + 1)$ among spenders.

Subgroup analyses (sex x arthritis) included an interaction test. Robustness analyses: (A) prevalent vs. incident decomposition; (B) one-wave-lagged exposure, and exclusion of participants whose last observation was at Wave ≤ 2 (early dropouts) as an attrition sensitivity; (C) four cognitive-decline definitions; (D) hip fracture as a complementary hard outcome. Person-time incidence rates (per 1,000 person-years) and Kaplan-Meier curves (for descriptive visualization) were computed. Two-sided $P < 0.05$ denoted significance. Analyses were performed in Python 3.13 with lifelines 0.30, statsmodels 0.14, and scipy 1.13.

Role of the funding source

No external funding was received for this analysis.

Results

Cohort characteristics

In the falls cohort, 4,285 (31.4%) of 13,661 Wave-1 participants reported arthritis; the arthritis group was older, more often female and rural, less likely to smoke, and had substantially higher comorbidity burden, depression prevalence, and ADL disability (Table 1). Hip, falls, and hospitalization event counts by outcome are reported in Table 2.

Table 1
Baseline characteristics of the falls cohort, by Wave-1 arthritis status (N = 13,661).

Characteristic	Arthritis (n = 4,285)	No arthritis (n = 9,376)	P
Age, years (mean +/- SD)	59.4 +/- 9.6	58.1 +/- 10.1	1.7e-13
Male, %	41.5	50.9	2.3e-24
Rural, %	63.5	56.5	2.0e-14
BMI, kg/m2 (mean +/- SD)	23.6 +/- 3.8	23.5 +/- 3.8	0.107
Depression (CESD-10 >= 10), %	46.6	28.2	4.0e-97
Ever smoker, %	34.8	40.9	2.1e-11
Ever drinker, %	35.7	38.9	2.7e-4
Comorbidities, n (mean +/- SD)	0.69 +/- 0.87	0.49 +/- 0.75	1.6e-41
ADL disability, %	22.9	9.8	4.4e-92
Education: elementary or below, %	51.0	40.5	-
Education: junior high, %	22.0	21.4	-
Education: senior high, %	18.3	22.8	-
Education: college or above, %	8.7	15.3	-

Table 2
Incidence of study outcomes by Wave-1 arthritis status.

Outcome	Cohort (Model-3)	Person-years	Events arth / no-arth	IR arth / 1,000 PY	IR non-arth / 1,000 PY
Falls	10,515	56,978	1,378 / 1,971	77.4	47.6
Hospitalization	11,507	76,634	1,690 / 2,726	66.0	49.3
Hip fracture/problem	12,425	95,539	-	-	-
Any OOP (per interval)	12,532	(intervals)	29.5% / 21.4%	-	-

Time-dependent Cox models

Falls. Across 25,045 person-intervals and 56,978 person-years (3,349 incident falls), arthritis was associated with progressively attenuated but persistently elevated hazard ratios: HR 1.57 (1.48–1.67) in Model 1, 1.49 (1.40–1.58) in Model 2, and 1.42 (1.32–1.52) in the fully adjusted model ($P = 1.3 \times 10^{-23}$) (Table 3). Kaplan-Meier curves diverged from the first follow-up wave onward (log-rank $P = 8.7 \times 10^{-49}$; Fig. 2). Other independent fall predictors included older age, depression (HR 1.30), comorbidity

count (HR 1.10 per condition), and ADL disability (HR 1.25). The arthritis x sex interaction was not significant (P = 0.25; HR for males 1.48, females 1.37; Table 4).

Table 3
Time-dependent Cox (falls, hospitalization) and pooled GEE (OOP) estimates for arthritis.

Outcome	Model 1 HR/OR (95% CI)	Model 2 HR/OR (95% CI)	Model 3 HR/OR (95% CI)	Model 3 P
Falls (HR)	1.57 (1.48–1.67)	1.49 (1.40–1.58)	1.42 (1.32–1.52)	1.3e-23
Hospitalization (HR)	1.33 (1.27–1.40)	1.31 (1.24–1.38)	1.18 (1.11–1.25)	5.5e-8
Any OOP spending (OR)	-	-	1.33 (1.25–1.42)	4.2e-19
OOP amount (log), spenders only	-	-	exp(b) 1.04 (0.96–1.12)	0.40

Hospitalization. Across 34,399 intervals and 76,634 person-years (4,416 hospitalizations), the Model-3 HR for arthritis was 1.18 (1.11–1.25) (P = 5.5 x 10⁻⁸). Sex-stratified HRs were 1.15 (males) and 1.20 (females). Other strong predictors: age, comorbidity count, ADL disability, and depression. Pooled estimates across outcomes, models, and subgroups are visualized in Fig. 3.

Out-of-pocket medical spending. Among 12,532 participants (26,347 intervals), the probability of any OOP spending was higher in arthritis participants (29.5% vs 21.4%); the adjusted OR was **1.33 (1.25–1.42)** (P = 4.2 x 10⁻¹⁹) (Table 3). Among spenders (n = 6,257), the geometric mean ratio for total OOP was 1.04 (0.96–1.12; P = 0.40), and median annual OOP was identical (3,000 CNY) between groups, indicating that arthritis increased the probability of incurring any OOP rather than the amount among those already spending.

Robustness analyses

Prevalent vs incident arthritis. Both exposures predicted falls (prevalent HR 1.44, 1.34–1.54; incident HR 1.23, 1.03–1.46) (Table 4). For hospitalization the prevalent HR was 1.17 (1.10–1.25), while the incident estimate was 1.11 (0.99–1.24; P = 0.09). The incident estimate for falls confirms that new-onset arthritis during follow-up was itself associated with elevated downstream risk, although with somewhat wider CIs reflecting the smaller exposed sub-sample.

One-wave-lagged exposure. For falls, the lag-1 estimate was 1.38 (1.26–1.50), essentially unchanged from the contemporaneous exposure, arguing against pure reverse causation. **Attrition sensitivity.** Excluding participants whose last observation was at Wave ≤ 2 left 10,059 fall-cohort and 11,037 hospitalization-cohort participants; Model-3 HRs were 1.43 (1.34–1.53) for falls and 1.20 (1.13–1.27) for hospitalization, confirming robustness to informative early dropout.

Cognitive decline. Across four definitions (≥ 3-point drop, ≥ 1-SD drop, memory drop ≥ 2, executive drop ≥ 2), Model-3 HRs for arthritis ranged from 0.99 to 1.01 with P > 0.7 in every case (Table 4). This consistent null result contrasts sharply with the strong positive associations for falls and hospitalization.

Hip fracture / problem. Hip-fracture/problem incidence was lower (n = 484 events in 12,425 Model-3 participants, 95,539 person-years), but the arthritis HR remained positive and significant: 1.20 (1.05–1.37; P = 7.4 x 10⁻³).

Table 4
Sensitivity and subgroup analyses (Model-3, time-dependent Cox unless noted).

Analysis	n_persons	n_events	HR (95% CI)	P
Falls - sex subgroup				
Males	5,014	1,365	1.48 (1.33–1.65)	7.5e-13
Females	5,501	1,984	1.37 (1.25–1.49)	4.1e-12
Arthritis x male interaction	10,515	3,349	1.08 (0.95–1.22)	0.25
Falls - exposure type				
Prevalent arthritis	10,515	3,349	1.44 (1.34–1.54)	3.7e-24
Incident arthritis	10,515	3,349	1.23 (1.03–1.46)	0.019
Lag-1 exposure	8,742	2,022	1.38 (1.26–1.50)	2.1e-12
Excluding early dropouts (last wave < = 2)	10,059	3,264	1.43 (1.34–1.53)	2.1e-24
Hospitalization - exposure type				
Prevalent arthritis	11,507	4,416	1.17 (1.10–1.25)	4.8e-7
Incident arthritis	11,507	4,416	1.11 (0.99–1.24)	0.087
Excluding early dropouts	11,037	4,298	1.20 (1.13–1.27)	3.4e-9
Cognitive decline (negative control)				
Total cognition drop > = 3	8,731	3,881	1.01 (0.94–1.08)	0.84
Total cognition drop > = 1 SD (3.5)	8,731	2,428	0.99 (0.91–1.07)	0.81
Memory drop > = 2	9,429	4,099	1.00 (0.94–1.06)	0.94
Executive drop > = 2	8,898	5,251	0.99 (0.94–1.05)	0.78
Hip fracture/problem (positive control)				
Crude	15,024	581	1.31 (1.16–1.47)	1.6e-5
Model 3	12,425	484	1.20 (1.05–1.37)	7.4e-3

Discussion

In this 9-year CHARLS analysis we show that, in middle-aged and older Chinese adults, self-reported arthritis, treated as a time-varying exposure carried forward across five waves, independently and persistently predicts incident falls (HR 1.42), incident overnight hospitalization (HR 1.18), and the probability of any OOP medical spending (OR 1.33), but does not predict cognitive decline (HR approximately 1.00). Prevalent and incident arthritis both elevated fall risk; the lag-1 sensitivity and attrition-exclusion analyses produced near-identical estimates; and the dose-response test across outcomes (falls > hospitalization > spending > cognition) was internally consistent.

Comparison with prior literature

Several CHARLS-based studies have examined arthritis and falls, but with key design differences. Lin et al. (2022) used baseline arthritis only and reported an HR of 1.27 in 45- to 59-year-olds for fall injuries requiring medical care [7]. Zhong et al. (preprint, 2025) used PSM and reported a lower fall odds among arthritis participants (OR 0.90), likely due to selection of the matched comparison and cross-sectional analysis [8]. Wang et al. (Scand J Rheumatol 2025) modeled OA/RA severity with restricted cubic splines and reported a 23.5% increase in fall risk [9]. The present analysis is distinguished by (i) time-updated exposure across five waves including the most recent (2020), (ii) joint estimation of falls, hospitalization, and OOP economic outcomes, (iii) decomposition into prevalent and incident arthritis, and (iv) outcome triangulation with a clearly negative control (cognitive decline) and a clearly positive control (hip fracture). Mechanistically, our finding that both prevalent and incident arthritis predict falls is consistent with the chronic-pain / muscle-weakness / proprioceptive-impairment pathway proposed in MOBILIZE Boston (adjusted rate ratio 1.53 for polyarticular pain) [14] and the 2023 systematic review and meta-analysis linking OA to falls and fractures (pooled effect approximately 1.3) [15].

Mechanisms

Four non-mutually-exclusive mechanisms can plausibly link arthritis to falls and hospitalization. First, pain-related quadriceps inhibition and reduced proprioception directly impair balance [16]. Second, the chronic systemic low-grade inflammation accompanying arthritis (IL-6, TNF-alpha, CRP) accelerates sarcopenia and frailty, both of which predict falls and hospitalization [17], and recent CHARLS-based work shows that combined metabolic-frailty profiles [18] and frailty transitions [19, 20] are themselves strongly associated with arthritis risk, indicating bidirectional pathways along this axis. Third, common comorbidities (depression, cardiovascular disease, diabetes) cluster with arthritis and may mediate or confound the association [21]. Fourth, arthritis may reduce physical activity, leading to deconditioning and a paradoxical increase in fall risk when patients do ambulate. Our adjustment for depression, comorbidity count, ADL disability, and BMI only partially attenuated the HRs (from 1.57 to 1.42 for falls), suggesting that residual confounding by unmeasured disease severity, polypharmacy, or pain intensity persists.

The cognitive-decline null is informative. It argues against a single shared neurodegenerative pathway and supports the specificity of the arthritis-falls/hospitalization link. Although arthritis and cognition share risk factors (age, depression, low education), and although arthritis may reduce cognitive

stimulation through activity limitation, we observed no detectable signal in four operationalizations of decline, mirroring the inconsistency in the prior literature: a meta-analysis of 19 observational studies reported a pooled RR of 1.42 for dementia or cognitive impairment in OA but with extreme heterogeneity ($I^2 > 95\%$) [22], whereas Quach & Burr (2023) [23, 24] and the MOBILIZE Boston study reported no OA-cognition link. Reverse causation and surveillance bias in clinic-based OA samples may partly explain the discrepancy.

The economic finding, that arthritis raises the probability of OOP spending without raising the amount among spenders, is consistent with the predominantly outpatient, low-margin nature of arthritis care in China (medication, intermittent physiotherapy), as opposed to high-cost catastrophic events. This pattern is policy-relevant: even modest increases in OOP frequency can accumulate to financial strain in low-income households.

Strengths and limitations

Strengths include: nine-year follow-up across five waves; time-varying exposure eliminating baseline-only bias; joint estimation of clinical, health-service, and economic outcomes; and negative-control (cognition) plus positive-control (hip) outcomes to triangulate the specificity of the effect. Limitations include: (i) self-reported physician-diagnosed arthritis, which under-ascertains early disease; (ii) self-reported outcomes subject to recall; (iii) attrition in CHARLS (~ 15% by Wave 5), partially addressed by the exclusion sensitivity; (iv) competing-risk analysis was not performed because linkage of mortality records to the analytic sample was not feasible in this version of the dataset; (v) the modeling assumption that missing covariate values are missing at random, which we cannot test directly; and (vi) inability to fully separate OA from RA or to localize arthritis (knee, hip, hand), although prior work suggests that lower-limb arthritis carries the strongest fall risk [16]. Finally, the time-dependent Cox estimator assumes the carry-forward exposure is correctly specified; the lag-1 sensitivity supports the temporal ordering of exposure and outcome.

Implications

Three clinical and policy implications follow. First, rheumatology and primary-care guidelines for arthritis in China should incorporate fall-prevention assessment (e.g., timed up-and-go, balance testing) and comorbidity management, with particular attention to patients with newly incident arthritis who may not yet have received preventive counseling. Second, the elevated OOP probability among arthritis patients, even at modest per-episode amounts, supports expansion of chronic-disease insurance reimbursement for outpatient arthritis care to reduce household financial burden. Third, the cognitive-decline null suggests that cognitive screening is not a priority for arthritis-specific prevention; resources should target falls, sarcopenia, and cardiovascular comorbidity instead.

Conclusions

Arthritis, whether already present at baseline or developing during follow-up, independently predicts falls, hospitalization, and any OOP medical spending in Chinese middle-aged and older adults over nine years.

The specificity of the association (strong for falls/hospitalization/spending, null for cognitive decline, and positive for hip fracture) supports a musculoskeletal rather than a neurodegenerative mechanism. Integration of fall-prevention, comorbidity management, and financial protection into routine arthritis care is warranted.

Abbreviations

ADL

activities of daily living

BMI

body mass index

CESD-10

10-item Center for Epidemiologic Studies Depression scale

CHARLS

China Health and Retirement Longitudinal Study

CI

confidence interval

GEE

generalized estimating equations

HR

hazard ratio

OOP

out-of-pocket

OR

odds ratio

PY

person-years

SD

standard deviation.

Declarations

Ethics approval and consent to participate.

CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015). All participants provided written informed consent. The present secondary analysis used de-identified data and was exempt from additional review.

Consent for publication. Not applicable.

Availability of data and materials. CHARLS data are publicly available at <https://charls.charlsdata.com>. The analysis code is available from the corresponding author on reasonable request.

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Conflict of Interest

The authors declare that they have no competing interests relevant to the content of this manuscript.

Author Contributions

[Y.Z.] conceived and designed the study, developed the analysis plan, and takes full responsibility for the integrity of the data and the accuracy of the analysis. [H.C. and S.Z.] acquired and curated the CHARLS data, managed the study database, and contributed to data quality control. [Y.W. and W.W.] performed the statistical analysis, verified the underlying data, and produced all tables and figures. [W.F.] interpreted the results, drafted the initial manuscript, and revised it critically for important intellectual content. [X.L.] supervised the study, provided methodological and clinical guidance, and gave final approval of the version to be submitted. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

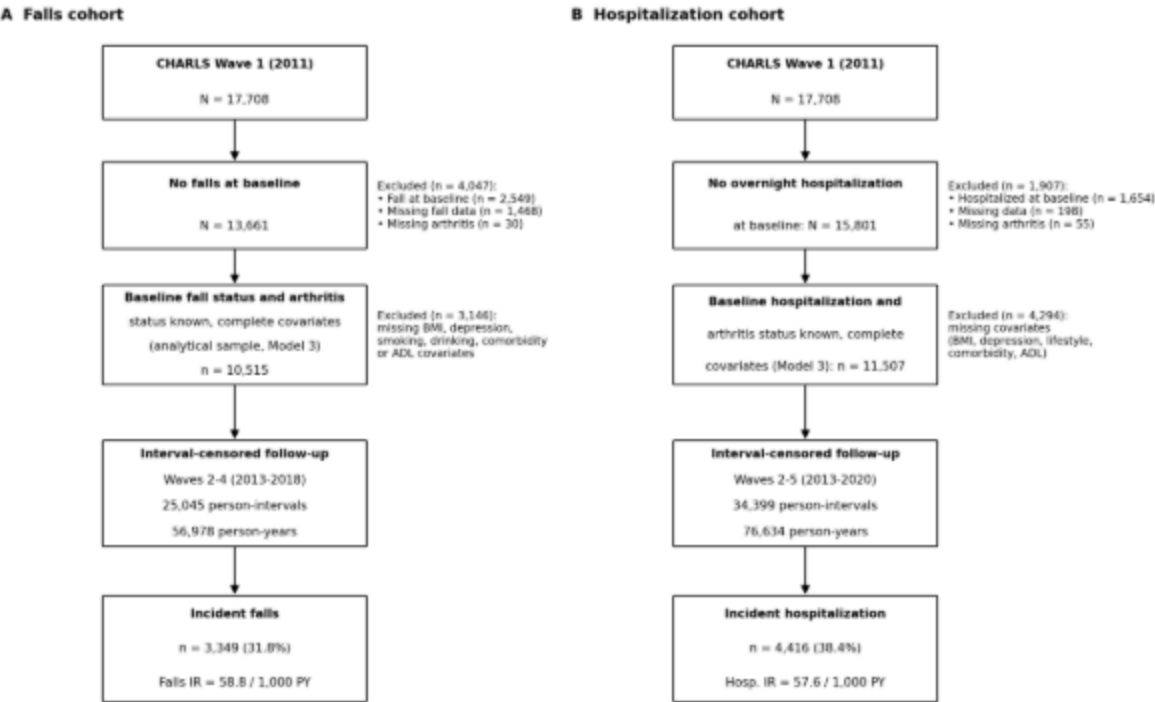


Figure 1 Cohort flow diagrams for the falls cohort (A) and the hospitalization cohort (B).

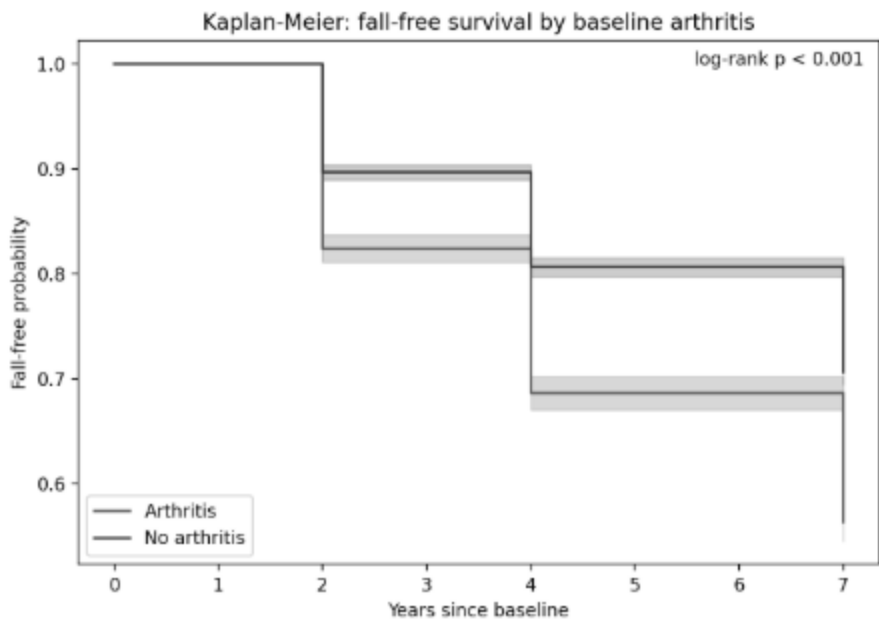


Figure 2

Kaplan-Meier fall-free survival curves by Wave-1 arthritis status (log-rank P < 0.001).

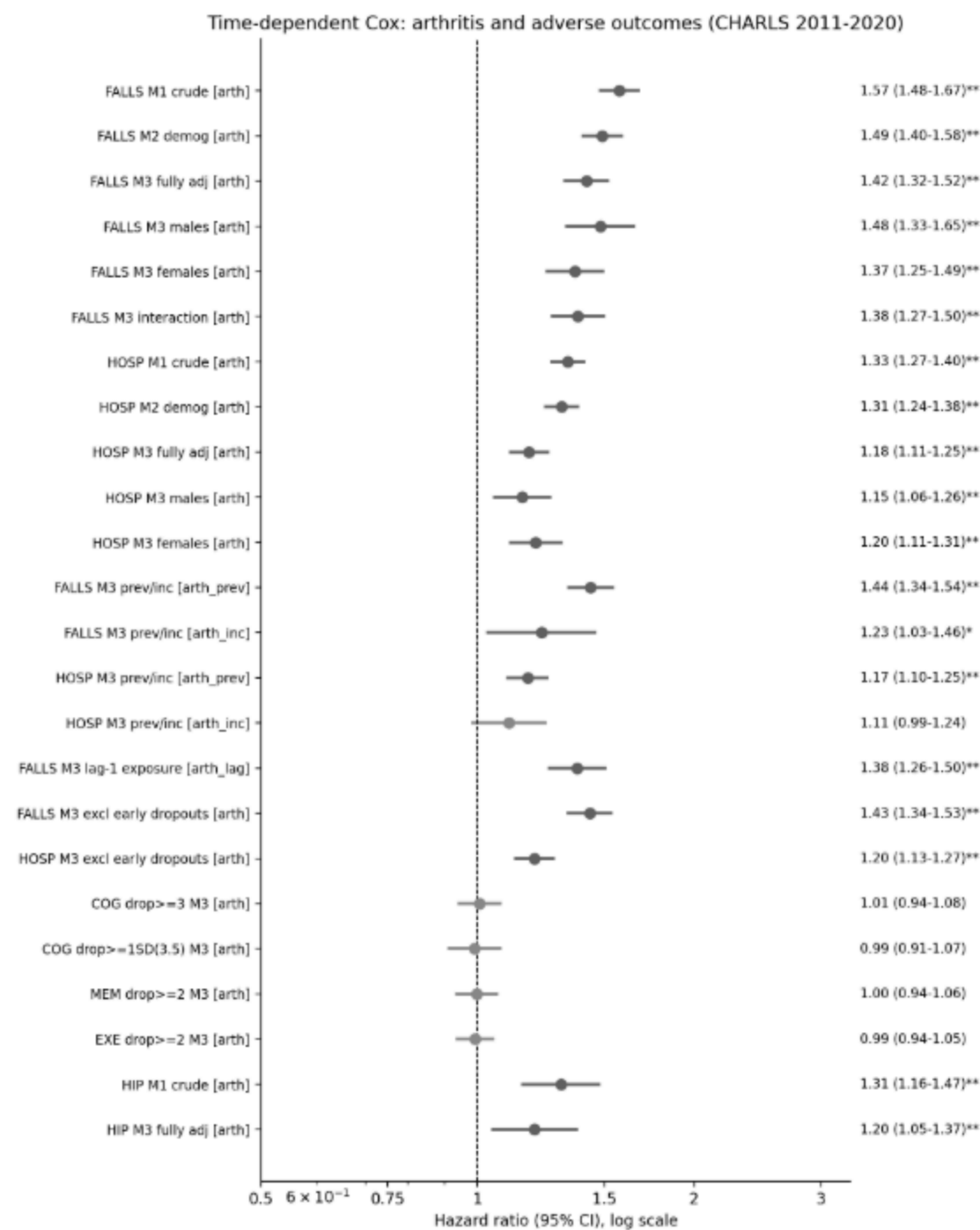


Figure 3

Forest plot of time-dependent Cox (and GEE) estimates for arthritis across outcomes, models, subgroups, and sensitivity analyses.