

Menopause and accelerated decline in the physical component of intrinsic capacity in Chinese women: a longitudinal cohort study

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Abstract

Background

Women, who live longer, face unique health challenges across the menopausal transition. Intrinsic capacity (IC), the composite of all physical and mental capacities that an individual can draw on, is central to the World Health Organization framework for healthy ageing. Whether the menopausal transition accelerates the decline of the physical component of IC in women has not been examined longitudinally. We estimated the association of menopausal status and years since menopause (YSM) with the rate of change in the physical component of IC, measured with objective performance tests, in a national cohort of Chinese women.

Methods

Participants were women from the 2011, 2013, and 2015 waves of the China Health and Retirement Longitudinal Study (CHARLS). The physical component of IC was measured with three performance domains (handgrip strength, gait speed, and balance), standardised within wave and combined into a continuous score by single-factor analysis. Menopausal status and age at menopause were obtained from self-reports, with midpoint imputation for women transitioning between waves. Linear mixed-effects models with random intercepts estimated the interaction of time with menopausal status (Model 1) and with time-varying YSM (Model 2), adjusting for baseline age, education, marital status, smoking, alcohol use, comorbidity, and body mass index (BMI).

Results

The analytic sample comprised 4,944 women (mean age 58.5 years at baseline), of whom 3,542 were postmenopausal in 2011. Relative to premenopausal women, postmenopausal women experienced an additional decline in the physical IC score of 0.026 standard deviation (SD) per year (time $\times$ menopausal status: $\beta = -0.0255$; 95% CI -0.0471 to -0.0040 ; $P = 0.020$). Each additional year since menopause was associated with an extra annual decline of 0.002 SD (time $\times$ YSM: $\beta = -0.0020$; 95% CI -0.0028 to -0.0013 ; $P < 0.001$). The estimated annual change in the score ranged from $+0.017$ SD at YSM = 0 to -0.013 SD at YSM = 15. Findings were consistent in random-slope models and were most pronounced among women aged ≥ 60 years.

Conclusions

In Chinese middle-aged and older women, menopause was associated with a faster decline in the physical component of intrinsic capacity, and the rate of decline increased with time since menopause. Monitoring physical capacity around the menopausal transition may help identify midlife women during

the perimenopausal period who would benefit from early targeted interventions to preserve physical capacity, thereby promoting healthy ageing specifically in women.

Background

As populations around the world grow older, preserving function in later life has become a priority for public health. The World Health Organization (WHO) defines intrinsic capacity (IC) as the composite of all the physical and mental capacities that an individual can draw on, and places its preservation at the centre of the healthy ageing agenda(1). Empirically, IC has been operationalised across five domains (locomotion, vitality, cognition, psychological well-being, and sensory function), using either self-reported limitations or objective performance tests(2). A longitudinal study in Chinese older adults showed that a multidimensional IC measure has a coherent one-factor structure and predicts subsequent disability in activities of daily living(3). Lower IC has also been linked to falls, frailty, institutionalisation, functional decline, and mortality in cohort studies and meta-analyses (4, 5).

In Chinese populations, trajectory studies based on the China Health and Retirement Longitudinal Study (CHARLS) show that IC declines with age along heterogeneous courses and that deterioration in specific domains can precede overall decline (6, 7). Cohort trends suggest that more recent Chinese birth cohorts enter old age with higher IC(8), while educational and life-course inequalities in IC remain wide [9]. Frailty, a construct closely related to IC, affects roughly 7% of community-dwelling Chinese older adults and shares similar determinants(10). Few of these studies, however, have asked whether specific life-course transitions change the pace of decline.

Menopause, the permanent cessation of ovarian function, occurs on average around age 50 and produces a marked fall in endogenous oestrogens. The menopausal transition has been associated with unfavourable changes in body composition, including loss of muscle mass and strength(11). In the Finnish Estrogenic Regulation of Muscle Apoptosis (ERMA) cohort, menopausal status was associated with lower muscle mass and physical performance, particularly among physically inactive women(12), and reviews link menopause with sarcopenia and frailty(13, 14). Longitudinal evidence further shows that menopause accelerates lung function decline beyond age-related changes(15), suggesting that the menopausal transition can speed the deterioration of several physiological systems.

In CHARLS, earlier age at menopause has been associated with worse cognitive performance and faster cognitive decline among Chinese women(16), and menopausal status modifies the association between sarcopenia and cardiovascular disease(17). Whether menopause also influences the trajectory of the physical component of IC has not been examined. Using three waves of CHARLS with objectively measured physical performance, we tested the hypothesis that postmenopausal status and longer time since menopause are associated with faster decline in the physical component of IC among middle-aged and older Chinese women.

Methods

Study design and participants

CHARLS is a nationally representative longitudinal survey of Chinese residents aged 45 years and older, with baseline interviews in 2011 and follow-up waves in 2013 and 2015; sampling and response details are described in the cohort profile(18). We included women who answered the menopause questions, were aged ≥ 45 years at baseline, had a determinable menopausal trajectory, and had an IC score in at least two of the three waves. CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants gave written informed consent. The present analysis used de-identified public-use data.

Menopause assessment

At each wave, women were asked whether menstruation had ceased permanently and, if so, at what age. Reported ages at menopause were restricted to 30–65 years. Because the 2014 life-history module was not available in the public-use data, age at menopause for women who transitioned between adjacent waves was imputed as the midpoint of their age at the two waves. Implausible reports were corrected: if a woman who reported premenopausal status at a wave also reported an age at menopause below her current age, the value was replaced with her current age plus 0.5 years. At each wave, women were classified as premenopausal or postmenopausal, and years since menopause (YSM) was computed as survey year minus age at menopause. YSM was treated as a time-varying exposure and coded 0 for premenopausal observations.

Physical component of intrinsic capacity

The physical component of IC was constructed from three objectively measured performance domains assessed at each wave: handgrip strength (maximum value, kg), usual gait speed over a 2.5-metre course (m/s), and standing balance scored from semi-tandem and full-tandem holds (combined 0–20 s, following the CHARLS protocol). The chair-stand test was not used because its records were largely missing in the public-use data. Each indicator was z-standardised within wave. A single-factor model was estimated by maximum-likelihood factor analysis of the pairwise complete correlation matrix, and the physical IC score for each observation was computed as the loading-weighted average of the available z-scores, requiring at least two of the three indicators. Higher scores indicate better capacity.

Covariates

Baseline covariates were age (years), education (below elementary, elementary, middle school, high school or above), marital status (married or partnered versus other), ever smoking, alcohol use (current or former versus never), the number of chronic conditions (0–14, from a checklist that included hypertension, diabetes, heart disease, stroke, chronic lung disease, arthritis, and others), and body mass index (BMI, kg/m²), computed from height and weight measured at the 2011 visit.

Statistical analysis

Baseline characteristics were compared between premenopausal and postmenopausal women with t-tests for continuous variables and chi-square tests for categorical variables. Trajectories of the physical IC score were modelled with linear mixed-effects models with random intercepts for individuals; time was coded as years since 2011 (0, 2, 4). Model 1 regressed the physical IC score on time, baseline menopausal status, and their interaction. Model 2 replaced menopausal status with time-varying YSM, again including the interaction with time. Both models adjusted for baseline age (centred at 60 years), education, marital status, smoking, alcohol use, comorbidity, and BMI. Degrees of freedom were approximated with the Satterthwaite method. Marginal predicted means were computed with the emmeans package at time 0, 2, and 4 years, by menopausal status and at YSM of 0, 5, 10, and 15 years. Sensitivity analyses added random slopes for time. Subgroup analyses were stratified by baseline age (< 60 versus ≥ 60 years). Analyses were performed in R version 4.6.1 with the lme4, lmerTest, and emmeans packages. Two-sided $P < 0.05$ was considered statistically significant.

Results

Study participants

Of 9,221 women interviewed in 2011, 8,447 answered the menopause question. After excluding women younger than 45 years ($n = 315$), those with an indeterminate menopausal trajectory ($n = 1,143$), those with the physical IC score measured in fewer than two waves ($n = 1,690$), and 355 women with missing covariates (mostly baseline BMI), 4,944 women formed the analytic sample (Fig. 1). These women contributed 13,035 person-wave observations (mean 2.6 per woman); 3,147 women (63.7%) had the score measured in all three waves. Baseline characteristics by menopausal status are shown in Table 1. Postmenopausal women were older (mean 62.1 versus 49.3 years), less educated, and had a lower baseline physical IC score (-0.13 versus 0.42 SD) than premenopausal women. Mean age at menopause was 49.3 (SD 4.6) years, and mean BMI was 24.0 kg/m^2 (SD 4.0), slightly higher in premenopausal than postmenopausal women (24.7 versus 23.8 kg/m^2).

Table 1
Baseline characteristics of the analytic sample by menopausal status at baseline (2011)

Characteristic	Overall (n = 4,944)	Premenopausal (n = 1,402)	Postmenopausal (n = 3,542)	P
Age, years, mean (SD)	58.5 (9.2)	49.3 (4.4)	62.1 (8.0)	< 0.001
Age at menopause, years, mean (SD) a	49.3 (4.6)	52.1 (4.3)	48.7 (4.5)	—
Education, n (%)				
Below elementary	2,954 (59.7)	570 (40.7)	2,384 (67.3)	
Elementary	898 (18.2)	299 (21.3)	599 (16.9)	
Middle school	757 (15.3)	379 (27.0)	378 (10.7)	
High school or above	335 (6.8)	154 (11.0)	181 (5.1)	< 0.001
Married or partnered, n (%)	3,982 (80.5)	1,220 (87.0)	2,762 (78.0)	< 0.001
Ever smoker, n (%)	402 (8.1)	79 (5.6)	323 (9.1)	< 0.001
Current or former drinker, n (%)	619 (12.5)	197 (14.1)	422 (11.9)	0.046
Comorbidity count, mean (SD)	1.4 (1.4)	1.2 (1.3)	1.5 (1.4)	< 0.001
BMI, kg/m ² , mean (SD)	24.0 (4.0)	24.7 (4.0)	23.8 (4.0)	< 0.001
Physical IC score in 2011, mean (SD)	0.03 (1.00)	0.42 (1.00)	-0.13 (0.95)	< 0.001
Continuous variables are presented as mean (SD), and categorical variables are presented as n (%). P values were calculated to compare baseline characteristics between premenopausal and postmenopausal women. The P value for age at menopause was not applicable because this variable was defined only among women who had experienced menopause.				
Abbreviations: BMI, body mass index; IC, intrinsic capacity; SD, standard deviation.				

Measurement properties of the physical IC score

The single-factor model fitted the three performance indicators with loadings of 0.64 for handgrip strength, 0.48 for gait speed, and 0.26 for balance; the factor accounted for 23.6% of the total variance.

Menopause and change in the physical component of intrinsic capacity

In Model 1, the physical IC score did not decline among premenopausal women over the 4-year window (time β = +0.0135 SD per year; 95% CI – 0.0062 to 0.0332; P = 0.178), whereas postmenopausal women declined at a rate 0.0255 SD per year faster (time $\times$ menopausal status β = –0.0255; 95% CI – 0.0471 to – 0.0040; P = 0.020; Table 2). In Model 2, the main effect of time was positive (β = +0.0173 SD per year; 95% CI 0.0057 to 0.0290; P = 0.004), and each additional year since menopause was associated with an extra annual decline of 0.0020 SD (time $\times$ YSM β = –0.0020; 95% CI – 0.0028 to – 0.0013; P = 1.8×10^{-7}). Models with random slopes for time gave nearly identical estimates (Model 1: β = –0.0251; 95% CI – 0.0470 to – 0.0032; P = 0.025; Model 2: β = –0.0020; 95% CI – 0.0028 to – 0.0012; P = 3.5×10^{-7}).

Table 2
Menopause and the rate of change in the physical component of intrinsic capacity: primary and sensitivity analyses

Analysis	Model	Interaction term	β (95% CI)	P
Primary	Model 1, random intercept	Time $\times$ menopausal status	–0.0255 (– 0.0471 to – 0.0040)	0.020
Primary	Model 2, random intercept	Time $\times$ YSM	–0.0020 (– 0.0028 to – 0.0013)	< 0.001
Sensitivity	Sensitivity Model 1, random slope	Time $\times$ menopausal status	–0.0251 (– 0.0470 to – 0.0032)	0.025
Sensitivity	Sensitivity Model 2, random slope	Time $\times$ YSM	–0.0020 (– 0.0028 to – 0.0012)	< 0.001
Values are interaction coefficients (β) with 95% confidence intervals (CIs) from linear mixed-effects models. Model 1 included the interaction between time and menopausal status, whereas Model 2 included the interaction between time and years since menopause (YSM). Primary models included a random intercept, whereas sensitivity analyses additionally included a random slope for time. All models were adjusted for baseline age, education, marital status, smoking status, drinking status, comorbidity count, body mass index (BMI), and physical activity. P values test the null hypothesis that the corresponding interaction coefficient equals zero.				

Marginal predicted means (Fig. 2, Table 4) illustrate the divergence. In Model 1, premenopausal women improved slightly, from 0.056 to 0.110 SD (+ 0.014 SD per year). Postmenopausal women declined over the same period, from 0.074 to 0.026 SD (– 0.012 SD per year). Model 2 showed a monotone gradient by YSM: the estimated annual change was + 0.017 SD at YSM = 0, + 0.007 SD at YSM = 5, – 0.003 SD at YSM = 10, and – 0.013 SD at YSM = 15 (Fig. 3).

Table 4
Marginal predicted means of the physical component of intrinsic capacity (SD units)

Panel A. Model 1, by menopausal status				
Time (years)	Premenopausal, mean (95% CI)		Postmenopausal, mean (95% CI)	
0	0.056 (– 0.007 to 0.120)		0.074 (0.022 to 0.127)	
2	0.083 (0.020 to 0.147)		0.050 (0.001 to 0.099)	
4	0.110 (0.026 to 0.195)		0.026 (– 0.026 to 0.078)	
Panel B. Model 2, by years since menopause				
Time (years)	Years since menopause (YSM)			
	YSM = 0	YSM = 5	YSM = 10	YSM = 15
0	0.069 (0.001 to 0.137)	0.070 (0.015 to 0.124)	0.070 (0.020 to 0.120)	0.071 (0.015 to 0.126)
2	0.104 (0.035 to 0.172)	0.084 (0.029 to 0.139)	0.064 (0.016 to 0.112)	0.044 (– 0.006 to 0.095)
4	0.138 (0.062 to 0.215)	0.098 (0.037 to 0.160)	0.058 (0.006 to 0.110)	0.018 (– 0.033 to 0.069)
Values are marginal predicted means (SD units) with 95% confidence intervals (CIs) derived from linearmixed-effects models adjusted for baseline age, education, marital status, smoking status, drinking status,comorbidities, body mass index, and physical activity.				

Subgroup analyses by baseline age

Among women aged ≥ 60 years at baseline, the interaction in Model 1 was in the same direction but not statistically significant ($\beta = -0.0923$; 95% CI – 0.2285 to 0.0439; $P = 0.184$), while the Model 2 interaction was more pronounced than in the full sample ($\beta = -0.0029$; 95% CI – 0.0042 to – 0.0017; $P = 4.7 \times 10^{-6}$; Table 3). Among women younger than 60 years, the Model 1 interaction was not significant ($\beta = +0.0056$; $P = 0.657$) and the Model 2 interaction was positive ($\beta = +0.0037$; 95% CI 0.0017 to 0.0058; $P = 3.8 \times 10^{-4}$), i.e. in the opposite direction (Table 3 and Additional file 1: Figure S1).

Table 3
Subgroup analyses by baseline age

Age group	Model	β (95% CI) for interaction	P
< 60 years	Model 1: time $\times$ menopausal status	+ 0.0056 (– 0.0193 to 0.0305)	0.657
< 60 years	Model 2: time $\times$ YSM	+ 0.0037 (0.0017 to 0.0058)	< 0.001
$\geq$ 60 years	Model 1: time $\times$ menopausal status	–0.0923 (– 0.2285 to 0.0439)	0.184
$\geq$ 60 years	Model 2: time $\times$ YSM	–0.0029 (– 0.0042 to – 0.0017)	< 0.001
In age-stratified analyses, the interaction between time and menopausal status was not statistically significant among women aged < 60 years (β = 0.0056, 95% CI – 0.0193 to 0.0305; P = 0.657) or those aged $\geq$ 60 years (β = –0.0923, 95% CI – 0.2285 to 0.0439; P = 0.184). In contrast, the interaction between time and YSM was statistically significant in both age groups, with a positive coefficient among women aged < 60 years (β = 0.0037, 95% CI 0.0017 to 0.0058; P < 0.001) and a negative coefficient among those aged $\geq$ 60 years (β = –0.0029, 95% CI – 0.0042 to – 0.0017; P < 0.001).			

Discussion

In this nationally representative cohort of 4,944 Chinese women followed over four years, postmenopausal status was associated with an additional decline in the physical component of IC of 0.026 SD per year, and longer time since menopause was associated with progressively faster decline. The estimates changed little when random slopes for time were added, and the associations were most evident among women aged 60 years or older. To our knowledge, this is the first longitudinal study linking menopausal status to the trajectory of the physical component of intrinsic capacity. These findings add to the growing literature on menopause-related physical decline and are among the first to demonstrate that such declines are captured by the WHO intrinsic capacity framework in a female-specific context (19).

Over the four years of follow-up, the estimated divergence between premenopausal and postmenopausal women was roughly 0.10 SD of the physical IC score, which is similar in size to the average four-year decline observed in Chinese community cohorts(6). A woman 15 years past menopause declined at about 0.013 SD per year, whereas a woman of the same age before menopause showed no decline and indeed improved slightly. The gradient across YSM categories strengthens the case for a causal interpretation.

These findings align with evidence that the oestrogen withdrawal of menopause contributes to loss of muscle mass and strength and can accelerate the decline of other physiological systems(11–15). Because the physical IC score integrates several performance domains, it may be a sensitive summary of these systemic changes. The parallel finding in CHARLS that earlier menopause is associated with faster cognitive decline suggests that the menopausal transition marks the onset of accelerated deterioration across multiple domains of capacity(16).

Two observations require interpretation, and we argue that both reflect the same phenomenon: practice effects in repeated performance testing. First, premenopausal women showed a slight improvement in the score (+ 0.014 SD per year). An improvement in objectively measured grip strength, gait speed, and balance over four years of ageing is biologically implausible, and learning effects are well documented in repeated performance tests, particularly among the most able participants. Postmenopausal women declined despite the same upward bias, so the estimated divergence is conservative and likely understates the true difference.

Second, among women younger than 60 years the time $\times$ YSM interaction was positive rather than negative ($\beta = +0.0037$; 95% CI 0.0017 to 0.0058; $P = 3.8 \times 10^{-4}$), and the interaction with menopausal status in the same subgroup was null ($P = 0.657$). We interpret this reversal as a methodological artefact rather than a biological effect. No known mechanism predicts that more years since menopause would slow the decline of physical capacity, and such a claim would contradict both the dose–response gradient in the full sample and the stronger associations in the older subgroup. Practice effects offer the most plausible explanation: they are concentrated among younger, higher-performing women, whose gains from repeated testing mask the comparatively small biological decline expected over four years at these ages, and whose menopausal status was still changing during follow-up. Consistent with this account, the associations were strongest where practice effects are weakest. Among women aged 60 and older, whose baseline performance was already low, both models showed accelerated decline, and the Model 2 interaction was more pronounced than in the full sample ($\beta = -0.0029$; 95% CI -0.0042 to -0.0017 ; $P = 4.7 \times 10^{-6}$). We therefore regard the accelerated decline in women aged 60 and older, together with the monotone YSM gradient in the full sample, as the core finding of this study.

From a women's health perspective, the years around the menopausal transition represent a critical window for monitoring physical capacity (20), as recommended in the WHO ICOPE framework. Incorporating simple physical performance assessments (e.g., grip strength, gait speed) into routine gynecological and primary care visits for midlife women could help identify those at risk (21). Early promotion of muscle-strengthening activities during this life stage may be particularly effective in preserving long-term physical independence in women (22).

Several limitations apply. Age at menopause was reconstructed from three waves of self-report, without the 2014 life-history module, so YSM is measured with some error; the resulting misclassification is most likely non-differential and would bias estimates toward the null. Natural and surgical menopause could not be distinguished in the 2011 wave. Our score captures only the physical component of IC; we did not examine the cognitive, psychological, or sensory domains, so the findings should not be read as applying to intrinsic capacity as a whole. Repeated testing may induce practice effects that bias slopes upward; we addressed this by interpreting subgroup patterns jointly, but it cannot be fully eliminated. Baseline BMI was missing for 355 women (6.7%), who were excluded; BMI may also lie on the causal pathway between menopause and physical capacity, although results with and without BMI adjustment were very similar, suggesting that over-adjustment is not a major concern. Residual confounding by

unmeasured factors such as hormone therapy use cannot be excluded. Finally, the sample is Chinese women aged 45 years and older, which limits generalisability to other populations.

Conclusions

Among middle-aged and older Chinese women, menopause was associated with accelerated decline in the physical component of intrinsic capacity, and the rate of decline rose with years since menopause, most clearly at ages 60 years and above. These findings point to the menopausal transition as a period when physical capacity should be monitored and when early intervention may help women maintain function into later life.

Abbreviations

CHARLS

China Health and Retirement Longitudinal Study

CI

confidence interval

ERMA

Estrogenic Regulation of Muscle Apoptosis

IC

intrinsic capacity

ICOPE

Integrated Care for Older People

SD

standard deviation

WHO

World Health Organization

YSM

years since menopause.

Declarations

Ethics approval and consent to participate

This study is a secondary analysis conducted in accordance with the Declaration of Helsinki. CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent. The present analysis used de-identified public-use data.

Consent for publication

Not applicable.

Clinical trial number

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

Lin Yang: Conceptualization, Methodology, Formal analysis, Software, Validation, Data curation, Writing – Original draft, Visualization. SenJun Deng: Supervision, Project administration, Methodology, Writing – Review & Editing. All authors read and approved the final manuscript.

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Data Availability

The data analysed in this study are publicly available from the China Health and Retirement Longitudinal Study (CHARLS) repository (<https://charls.pku.edu.cn/en/>). Access requires registration and approval from the CHARLS team. The analytical code is available from the corresponding author upon reasonable request.

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Figures

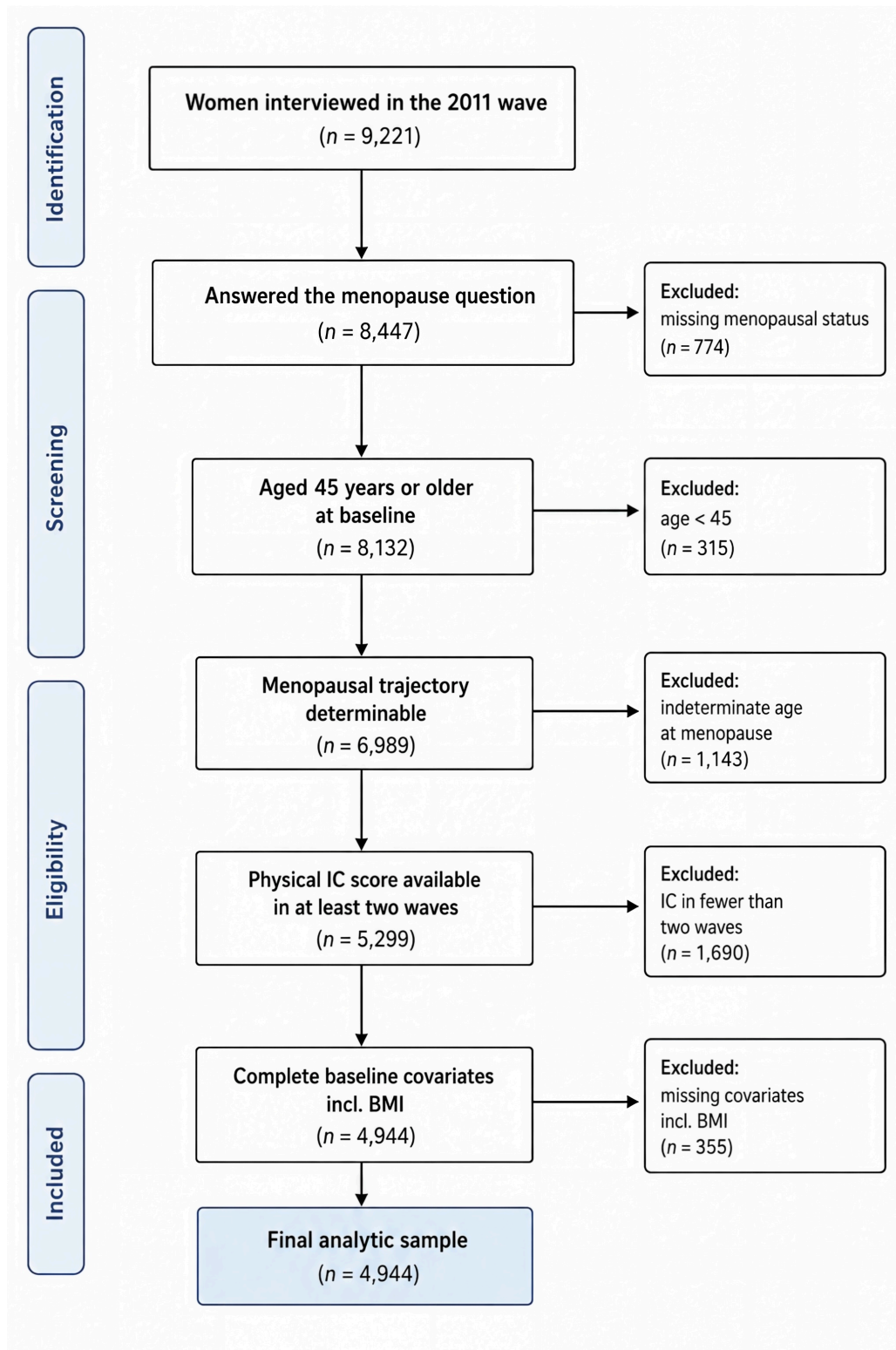


Figure 1

Flow of participants through the study.

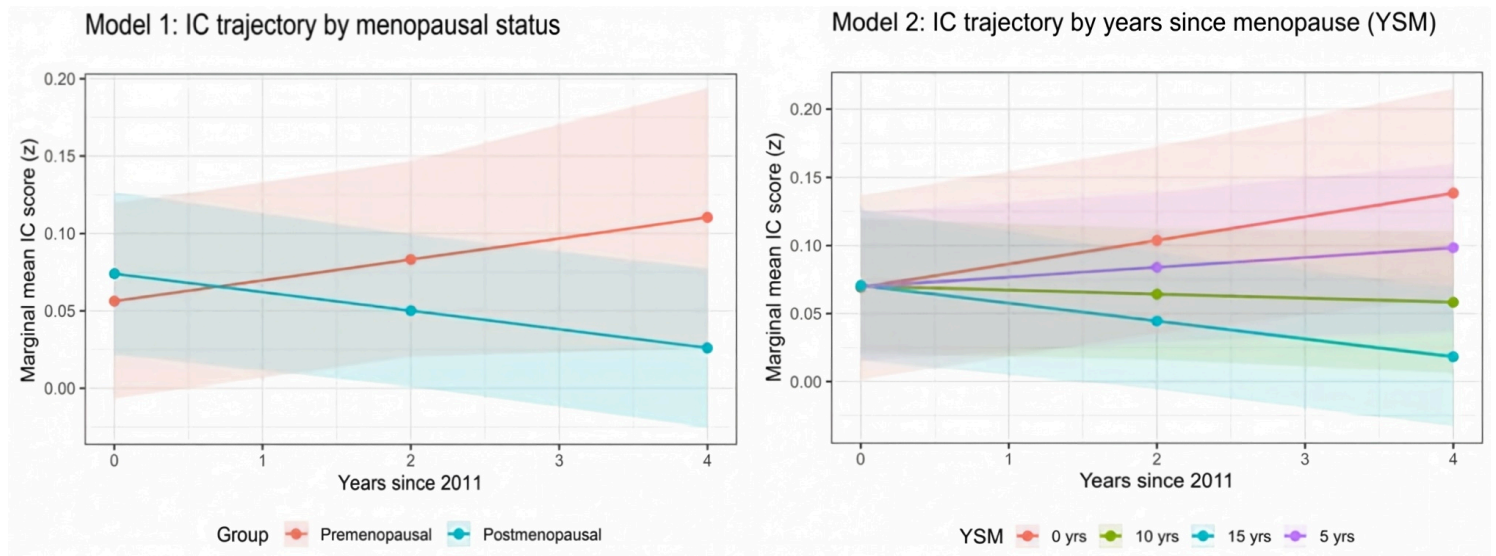


Figure 2

Marginal predicted means of the physical component of intrinsic capacity (SD units) by time. (A) Model 1, stratified by menopausal status at baseline (premenopausal vs. postmenopausal). (B) Model 2, stratified by years since menopause (YSM = 0, 5, 10, and 15 years). Estimates were adjusted for baseline age, education, marital status, smoking, alcohol use, comorbidity, and body mass index. Error bars represent 95% confidence intervals.

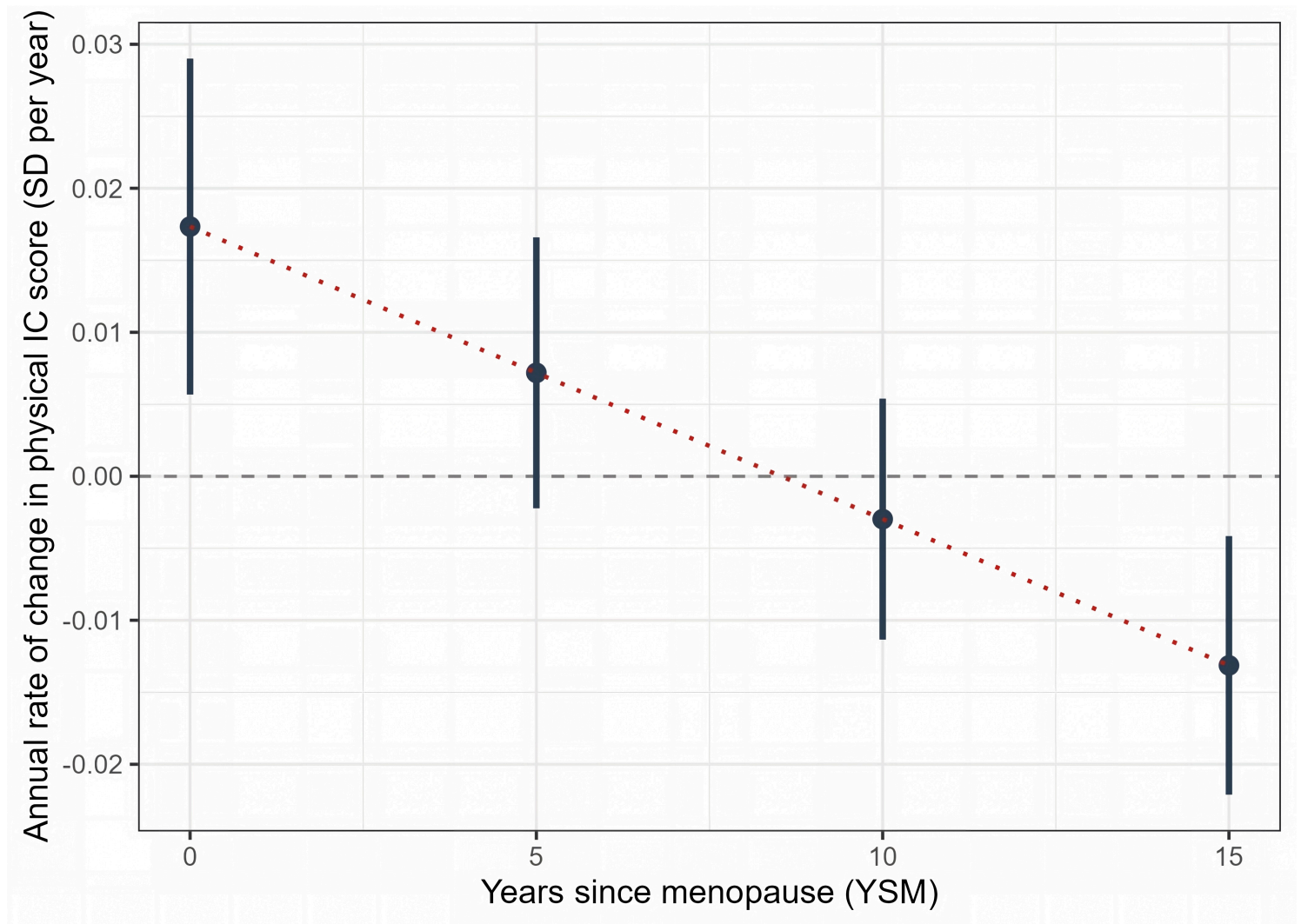


Figure 3

Annual rate of change in the physical component of intrinsic capacity (SD per year) by years since menopause, estimated from Model 2 as marginal time slopes at YSM = 0, 5, 10, and 15 years with 95% confidence intervals. The dotted line is the fitted linear trend: each additional year since menopause was associated with a further 0.0020 SD per year decline in the annual rate of change (the time $\times$ YSM interaction).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [FigureS1.pdf](#)