A New Path to Address Multimorbidity? Longitudinal Analyses of Retirement Sequences and Chronic Diseases in Old Age

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Abstract

Chronic disease and multimorbidity are growing health challenges for aging populations, often coinciding with retirement. We examine late-life predictors of multimorbidity, focusing on the association between retirement sequences and number of chronic diseases. We modeled the number of chronic diseases as a function of six-types of previously identified 10-year retirement sequences using HRS data for 7,880 Americans observed between ages 60-61 and 70-71. Our results show that at baseline, the adjusted prevalence of multimorbidity was lowest in sequences characterized by late retirement from full-time work and highest in sequences characterized by early labor-force disengagement. Age increases in multimorbidity varied across retirement sequences, though overall differences in prevalence persisted at age 70-71. Earlier-life disadvantages did not moderate these associations. Findings suggest further investigation of policies that target health limitations affecting work, promote continued beneficial employment opportunities, and ultimately leverage retirement sequences as a novel path to influence multimorbidity in old age.

Keywords: non-communicable disease, work, labor force, career, trajectory

A New Path to Address Multimorbidity? Longitudinal Analyses of Retirement Sequences and Chronic Diseases in Old Age

Chronic diseases and the co-occurrence of two or more chronic diseases (multimorbidity) are increasingly prevalent in aging populations and pose considerable challenges for patients' quality of life, medical practice, and health-related policy (Dugravot et al., 2020; Nugent et al., 2018). Relative to individuals with one or no chronic diseases, multimorbid patients are hospitalized and re-hospitalized more frequently and for longer periods, use more health care services, make higher out-of-pocket payments, experience stress with multiple instructions from several specialized physicians, suffer adverse effects of polypharmacy, and experience increased risk of dependency and mortality (Nunes, Flores, Mielke, Thume, & Facchini, 2016; Salive, 2013; Wei, Ratz, & Mukamal, 2020). The financial consequences for patients and governments are sizable (Glynn et al., 2011; Nugent et al., 2018).

The number of chronic diseases and risk for multimorbidity increase with age (Kingston et al., 2018; Stenholm et al., 2015). At least half of adults aged 60 and over report more than one chronic disease, making multimorbidity the norm among this age group (Salive, 2013; Wei et al., 2020). Given financial pressures to delay retirement and the rising share of older workers in many countries, understanding the progression of chronic diseases toward multimorbidity among those near retirement age is increasingly important (Staudinger, Finkelstein, Calvo, & Sivaramakrishnan, 2016). Having more chronic conditions negatively affects labor market participation of older adults and is associated with transitions to unemployment, disability, and retirement (Cabral, Dantas de Souza, Barbosa, Jerez-Roig, & Souza, 2019; de Boer et al., 2018; van Zon et al., 2020). Growing evidence suggests that the causal relationship is bidirectional: non-working status and transitions into unemployment and retirement also increase the

probability of having one or more chronic conditions (Allel, León, Staudinger, & Calvo, 2019; Hessel, 2016; Staudinger et al., 2016).

The vast majority of this research focuses on labor-force status and transitions as discrete events. In this study, we analyze longitudinal associations between 10-year-long types of retirement sequences and trajectories of chronic diseases in old age. These retirement sequences encompass chronologically ordered labor-force status and transitions within individuals from ages 60-61 to 70-71. Six types were identified in previous research (E. Calvo, Madero-Cabib, & Staudinger, 2018): *early* (completely retired by or before age 62), *ambiguous* (from out of the labor force to retirement), *complete* (completely retired from a full-time job around normative age 66), *late* (full-time work after age 66), *partial* (from full-time work to partial retirement around age 66), and *compact* (from part-time work to partial retirement). This sequence approach has proven useful to inform policies that promote productive and healthy aging, such as remaining partially engaged in the labor force (Azar, Staudinger, Slachevsky, Madero-Cabib, & Calvo, 2019). The type of retirement sequence that individuals follow conveys information beyond the initial or final labor-force status and specific transitions in between, information that can improve our understanding of chronic conditions and multimorbidity in later life.

The purpose of this study is to examine late-life predictors of multimorbidity, focusing on associations between sequences that characterize the progression from work to retirement and age-trajectories of the number of chronic diseases people experience from age 60-61 to 70-71. The major hypothesis is that age-trajectories of chronic diseases vary with retirement sequences. Based on previous evidence suggesting a bidirectional relationship, we hypothesized that both the baseline (intercept) and the age increase (slope) in the number of chronic diseases would vary across sequences. We expected a disproportionally higher prevalence of multimorbidity for

individuals in retirement sequences characterized by weaker attachment to the labor force (*early* and *ambiguous*) from age 60-61 until age 70-71, relative to other sequences. We examined whether results held after adjusting for earlier-life disadvantages, sociodemographics, and health covariates, and stratified our analyses by earlier-life disadvantages and gender. We anticipated potential relevance of retirement sequences to gerontological policy and practice, regarding multimorbidity in this age group.

Methods

Study population

We use Health and Retirement Study's (HRS) nationally representative and longitudinal data for 9,752 individuals born between 1931 and 1941 and observed biannually since 1992, limiting the sample to individuals interviewed 6 times between ages 60-61 and 70-71 (see Table S1), conducting a single stochastic imputation of 19.76% missing data points, and dropping imputed Ys (Sullivan, Salter, Ryan, & Lee, 2015). Although women and healthier respondents were less likely to have missing data, selectivity effects by other variables were overall fairly small. Because the data were missing at random (MAR) and not completely at random (MCAR), listwise deletion would have been less appropriate than a stochastic imputation, in which chained equations iteratively predict the pattern of data missingness on one variable from other observed variables in the model, adding a random component to compensate for potentially lower standard errors. The imputation model considered all variables in our regression models and supplementary demographic, socioeconomic, and health-related variables. The final dataset includes 47,280 observations for 7,880 individuals. HRS data are publicly available to registered users and comply with the ethical requirements of the University of Michigan's Institutional Review Board.

Measures

Main outcome. We measure the number of chronic diseases between ages 60-61 and 70-71 as the time-varying sum score of eight dichotomies indicating whether the respondent reports ever having been diagnosed by a doctor with: (1) high blood pressure or hypertension, (2) diabetes or high blood sugar, (3) cancer or malignant tumor (except skin cancer), (4) chronic lung disease (except asthma), (5) heart problems (myocardial infarction, coronary heart disease, angina, congestive heart failure, or other heart problems), (6) stroke or transient ischemic attack, (7) emotional, nervous, or psychiatric problems, and (8) arthritis or rheumatism (Cigolle, Nagel, Blaum, Liang, & Quinones, 2018; Salive, 2013).

Main exposure. Our main exposures include age, retirement sequences, and their interaction term. Age is measured in two-year intervals beginning at 60-61 (coded as 0) and ending at 70-71 (coded as 5). Retirement sequences summarize labor-force patterns from ages 60-61 to 70-71 and are classified by six time-invariant dichotomies indicating: (1) *early* retirement from full-time jobs; (2) *complete* retirement at normative ages from full-time jobs; (3) *partial* retirement from full-time jobs; (4) *late* retirement from full-time jobs; (5) *ambiguous* retirement after being out of the labor force; and (6) a *compact* progression from part-time jobs to partial retirement. For more details about these retirement sequences, see the indicator resulting from the sequence analysis conducted by Calvo, Madero-Cabib, and Staudinger (E. Calvo et al., 2018), to chronologically order labor-force status (working full-time, working part-time, partly retired, completely retired, unemployed, disabled, not in the labor force) and transitions between these statuses.

Covariates. We adjust for a wide range of factors accounting for observed selectivity, composition bias, and common causes of both retirement sequences and trajectories in chronic

diseases. *Earlier-life disadvantages* include: childhood socioeconomic status as indicated by years of education of the highest educated parent (Fahy et al., 2017; Pavela & Latham, 2016); cumulative stress exposure, measured as allostatic load (index averaging the z scores of: C-reactive protein, glycated hemoglobin, high-density lipoprotein cholesterol, total cholesterol, BMI, waist circumference, systolic and diastolic blood pressure) (Delpierre et al., 2016; Stephan, Sutin, Luchetti, & Terracciano, 2016), and a count of childhood traumas ranging from 0 to 7 (including whether the respondent experienced any of the following adversities before age 18: relocating due to financial difficulties, receiving financial help, living with an unemployed father, getting in trouble with the police, repeating a year of school, being physically abused by either parent, or having a parent drink or use drugs often and in problematic ways) (Henchoz et al., 2019; Willis, Staudinger, Factor-Litvak, & Calvo, 2019). *Sociodemographics* include: gender, race/ethnicity (White non-Hispanic, Black non-Hispanic, Other non-Hispanic, Hispanic), educational level (less than 12 years of education, 12 years, more than 12 years), and type of occupation for job longest held (white-, pink-, and blue-collar worker, never worked) (Dugravot et al., 2020; Nunes et al., 2016; Salive, 2013). *Time-varying health covariates* include: self-reported health (five-points from poor to excellent), depressive symptomatology (8-symptoms, reduced version of the CES-D scale), limitations to perform 10 activities of daily living (ADL), body mass index (BMI) categories (underweight, normal, overweight, obese), drinking (abstainer, soft, moderate, heavy), and smoking status (never, ever, current) (Salive, 2013).

Statistical analyses

We use longitudinal mixed-effects Poisson regressions to model intercepts (at age 60-61) and slopes in the count distribution of chronic diseases across age (up to age 70-71). These models are also known as age-trajectory models or multilevel models with repeated observations

across time hierarchically nested within individuals. In order to address possible issues of a zero-inflated distribution and overdispersion, we estimated both Poisson and negative binomial models assuming zero-inflated and non-zero-inflated distributions. Because these results did not show an indication of overdispersion or a zero-inflated distribution, we use and report traditional Poisson models. We estimate three models. Null model 1 is used to calculate explained individual-variance in the number of chronic diseases. Model 2 includes age and retirement sequences interaction-terms, allowing chronic diseases' trajectories to vary across sequences. Quadratic and cubic age-terms were not significant. Model 3 is fully adjusted by earlier-life disadvantages, sociodemographics, and health covariates. In order to test possible gender differences, we estimated model 3 for each subsample of men and women separately. Stratified models (half-samples) based on parental SES and allostatic load led to largely consistent results and thus are not reported.

In all models we present incidence rate ratios (IRR), which compare two incidence rates (or occurrences of chronic diseases over person-time). An IRR over 1 indicates that the exposed (numerator) are at increased risk of experiencing a higher number of chronic diseases relative to the non-exposed (denominator), and a value below 1 indicates the opposite. To facilitate the interpretation of results, we estimate and plot the predicted number of chronic diseases and probability of multimorbidity by type of retirement sequence and age, based on the coefficients of our regression models and the observed characteristics of each individual at each point in time.

Results

Participants' mean age was 65.5 years, 55.1% were women, and 73.2% were White non-Hispanic (E. Calvo et al., 2018). Table 1 shows descriptive statistics by retirement sequences,

using the *complete* sequence as the reference category. The top rows show the number of chronic diseases and percentage of multimorbid individuals (2+ chronic diseases) within each retirement sequence at ages 60-61 and 70-71 (see Figure 1), and the remaining rows show the distribution of all independent variables included in the regression models, across sequences. At baseline, the *partial* and *late* retirement sequences have the lowest unadjusted prevalence of multimorbid individuals (37.2% and 38.0%), while *early* and *ambiguous* have more than half of individuals with multimorbidity (50.7% and 50.4%). At age 70-71 the unadjusted distribution across sequences is more homogenous, and the difference between the sequences with the highest (*early*) and lowest (*late*) proportion of multimorbidity is less than 10 percent points.

[TABLE 1 HERE]

[FIGURE 1 HERE]

Table 1 also shows substantial variation in the composition of retirement sequences by earlier-life disadvantages, sociodemographics, and health-related variables. Notably, women represent 94.9% of the *ambiguous* sequence and 36.2% of the *late* sequence.

Table 2 reports regression results. Model 1 partitions variance without including any variables. Using the *complete* sequence as a reference, model 2 shows that the baseline number of chronic diseases (at age 60-61) is significantly lower for individuals in *partial* (IRR=0.87, $p<0.001$) or *late* sequences (IRR=0.90, $p=0.011$), while higher in *ambiguous* (IRR=1.13, $p=0.004$) and *early* sequences (IRR=1.15, $p<0.001$). Consistent with descriptive results, model 2 also shows that individuals in *early* or *ambiguous* sequences have slower increases in the number of chronic diseases over time (IRR=0.98, $p<0.001$ and IRR=0.98, $p=0.003$ respectively). These results are consistent with our hypothesis that both the baseline (intercept) and the age increase (slope) in the number of chronic diseases vary across sequences. With the exception of the

intercept for *ambiguous*, model 3 shows that these differences in intercepts and slopes are not fully explained by earlier-life disadvantages, sociodemographics, and health covariates. Differences across models in individual-level variance, going from 0.66 in null model 1 to 0.48 in full model 3, suggests that model 3 explains 27% of between-individuals' variance.

[TABLE 2 HERE]

Based on the coefficients obtained in model 3, we estimated the predicted number of chronic conditions, and the predicted probability of multimorbidity. The model accurately predicts the number of chronic conditions for over 60% of the sample, and the probability of multimorbidity for over 92% of the sample, suggesting good model performance overall (see Figure S1). Figure 2 shows multimorbidity age trajectories for each sequence based on these results, and Figure S2 focuses on selected sequences. We find that *partial, late,* and *compact* sequences have less than 50% of multimorbid individuals until ages 62-63. At ages 64-65 all sequences show a predicted probability of being multimorbid that is over 50%, except *partial* and *late,* whose individuals' also experience healthier trajectories than individuals in the *complete* sequence. As expected, we find that the prevalence of multimorbidity is overall higher for individuals in retirement sequences characterized by weaker attachment to the labor force (*early* and *ambiguous*) than for individuals in other sequences, but these differences are more pronounced at age 60-61 than at age 70-71.

[FIGURE 2 HERE]

Stratified models for men and women suggest that the associations between retirement sequences and chronic diseases are moderated by gender. The age increase in chronic conditions remains significant and very similar across groups. Nevertheless, the associations between sequences and chronic diseases changes. For men, the sequences characterized by *partial* and

late retirement are no longer associated with a lower estimated number of chronic diseases at age 60-61. These sequences, though, are significantly associated with a lower number of chronic diseases at baseline for women (IRR=0.88, p=0.012 for *partial*; 0.83, p=0.001 for *late*). The *early* retirement sequence is significantly associated with a higher baseline number of chronic diseases only for men (IRR=1.13, p=0.04). The age increase in chronic diseases is slower for both men and women in the *early* sequence (IRR=0.98, p=0.002 for men; IRR=0.98, p=0.27 for women). Furthermore, men in the *late* sequence experience slower age increases in chronic diseases relative to individuals in the *complete* sequence (IRR=0.98, p=0.042). Earlier-life disadvantages did not moderate the associations between retirement sequences and number of chronic diseases.

Discussion

Using longitudinal data for older Americans, we found that the number of chronic diseases is associated with the type of retirement sequence individuals follow in their 60s. This variation was not fully explained by earlier-life disadvantages, sociodemographics, and health covariates. The association between retirement sequences and multimorbidity was stratified by gender, but not earlier-life disadvantages.

Consistent with previous evidence that more chronic conditions negatively affect labor market participation of older adults (Cabral et al., 2019; de Boer et al., 2018; Staudinger et al., 2016; van Zon et al., 2020), we found that individuals begin retirement sequences with different probabilities of being multimorbid. Overall, relative to individuals in the *complete* sequence who completely retire at normative ages from full time jobs, the baseline number of chronic diseases was lower for individuals who followed sequences characterized by *partial* and *late* retirements from full-time jobs, while higher for individuals who follow sequences characterized by weaker

attachment to the labor force (*early* and *ambiguous*). We found that women drove the lower baseline levels of chronic conditions for the *partial* and *late* retirement sequences, while men drove the higher levels for the *early* sequence.

Partly consistent with previous evidence that non-working status and transitions into unemployment and retirement increase the probability of having chronic conditions (Allel et al., 2019; Hessel, 2016; Staudinger et al., 2016), we found that age-related increases in the number of chronic diseases (Kingston et al., 2018; Stenholm et al., 2015) were more pronounced in sequences characterized by weak ties to the labor force through ages 70-71. However, men in the *late*, and surprisingly also men and women in the *early* and *ambiguous* retirement sequences, experienced slower increases than individuals in the *complete* sequence.

These findings held after adjusting for earlier-life disadvantages, demographics, and health covariates, suggesting that retirement sequences may constitute a new window of opportunity to influence multimorbidity in old age. This possibility is reinforced by our finding that earlier-life disadvantages do not moderate the associations between retirement sequences and the number of chronic diseases. Regardless of their earlier-life disadvantages, retirement sequences seem to contribute to the progression of chronic diseases toward multimorbidity, and thus point to an important area for exploration and development of policies and interventions.

Our results are not without limitations. Chronic diseases are self-reported and might include ceiling effects and inconsistencies over time (Cigolle et al., 2018), though widely used in epidemiological research and adequately validated among older adults (Salive, 2013). Future research should explore the effects of later-life labor-force patterns on clusters of chronic diseases (that are treated together), complex multimorbidity (4+ diseases) (Kingston et al., 2018), and multimorbidity-weighted indices (Wei et al., 2020), disentangling age from period and

cohort effects. Potential for unobserved selection bias, reverse causation, and endogeneity may arise from the effects of health on labor-force decisions. This problem manifests in the estimated intercept of the models, indicating that individuals who retire early or are already out of the labor force report more chronic diseases. The estimated slope, however, may be less sensitive to selection bias due to mortality, as mortality over the observed period was clearly associated to our outcome but less so to our exposure. Relative to survivors, the few individuals who died over the observed period (see Table S1) were likely to report more chronic diseases, especially chronic diseases with a high case fatality rate. However, individuals that died over the observed period clustered in a separate type of retirement sequence (E. Calvo et al., 2018); thus, mortality over the observed period was weakly associated with the six types of retirement sequences included in this study.

When trying to estimate causal effects on chronic conditions, previous studies have relied on instrumental variables, regression discontinuities, and other counterfactual analytic techniques that account for unobserved selection and endogeneity bias (Hedström & Ylikoski, 2010). These analytic techniques are useful to compare treated and untreated individuals when focusing on dichotomous labor-force status and transitions (Esteban Calvo, Sarkisian, & Tamborini, 2013), but pose additional challenges to estimate causal effects of retirement sequences encompassing six types and their interaction with age.

Significance of our findings includes identifying late-life windows of opportunity to address multimorbidity, whereas extant literature has disproportionally focused on estimating prevalence, incidence, costs, and earlier-life predictors of multimorbidity, including sociodemographic, lifestyle, and environmental factors (Henchoz et al., 2019; Salive, 2013; Wei et al., 2020). Our approach is novel in simultaneously considering retirement sequences, earlier-

life disadvantages, and gender differences. We study entire retirement sequences between ages 60-61 and 70-71, which convey richer information than discrete labor-force statuses and transitions (Azar et al., 2019; E. Calvo et al., 2018). We leverage retrospective, biomarker, and anthropometric data to adjust for disadvantages accumulated earlier in life (Fisher, Chaffee, & Sonnega, 2016; Humphreys, Jameson, Cooper, & Dennison, 2018). Responding to calls in previous research for more attention to group differences, we obtain gender-specific estimates (Staudinger et al., 2016).

Our findings suggest that the associations between retirement sequences and multimorbidity were significant, multifaceted, and not stratified nor moderated by earlier-life disadvantages. This indicates a novel area for clinical, public health, and policy interventions: to maximize older adults' health and functionality in later life, the nexus of work experiences and chronic health conditions experienced concurrently in older adulthood should be leveraged. Health trajectories of older adults in their 60s generally benefit from continued engagement in the labor force. Further investigation of causal relationships between clinical approaches and policies that may influence retirement sequences to promote health is needed. If promoting health-maximizing retirement sequences through care and policy effectively staved off some multimorbidity, and optimized healthy work engagement of older adults, it could yield substantial benefits (Glynn et al., 2011; Nugent et al., 2018; Nunes et al., 2016).

To illustrate the magnitude of these potential benefits, we estimated the average annual total health care cost per patient by retirement sequence based on our estimated associations (not causal) and calculations made by Glynn and colleagues (Glynn et al., 2011), who predicted the average sum of primary care consultations, hospital outpatient visits, and hospital admissions for patients with varying numbers of chronic diseases (see Table S2). Assuming a true causal

relationship and interventions/policies successful in moving individuals from *early* to *partial* or *late* retirement sequences, the smaller number of chronic diseases would result in 7 billion dollars' savings in total health care costs over a decade. We do not have yet, however, strong causal evidence. Furthermore, these interventions and policy changes are not simple and mechanical. Nudging people toward some retirement sequences would be challenging given the financial pressures and personal issues surrounding retirement. Opportunities include developing evidence-based interventions to target health limitations affecting work among older workers (manage pain, reduce fatigue and weakness, improve function, minimize risk of falls), expanding geriatric training and care, promoting continued beneficial employment opportunities, and investing in older adults' education (Aldington & Ecclestone, 2019; Allel et al., 2019; Rowe, Fulmer, & Fried, 2016; Staudinger et al., 2016; Vanajan, Bultmann, & Henkens, 2020; Whitty et al., 2020). Considering gender differences in health and labor-force patterns when addressing policies that seek to prevent or delay multimorbidity also is needed (Staudinger et al., 2016).

Research that examines novel correlates of multimorbidity in later life can inform the development of policy and interventions designed to mitigate the individual burden associated with multimorbidity as well as societal costs. As the majority of clinicians and healthcare systems are organized to treat single health conditions, with little communication among providers (Boehmer, Abu Dabrh, Gionfriddo, Erwin, & Montori, 2018), the majority of labor-force policies target a single status or transition—like unemployment or retirement—with less attention to sequences of experience with work, and with little coordination across sectors (E. Calvo et al., 2018). We advocate for a focus on multimorbidity and retirement sequences to inform clinical practice and policy, above and beyond single chronic diseases and snapshot labor-force statuses and transitions. While actively engaging in healthcare reform and early-life

prevention (Boehmer et al., 2018; Henchoz et al., 2019), identifying novel late-life determinants of the onset of chronic diseases and progression toward multimorbidity is crucial to promote health in aging populations.

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Table 1. Sample characteristics by type of retirement sequence

	Complete (N=1,446)	Partial (N=1,224)	Early (N=2,889)	Late (N=920)	Ambiguous (N=865)	Compact (N=536)
Chronic diseases and multimorbidity						
Chronic diseases at age 60-61 (0-8)	1.6 (1.6)	1.4 (1.4)*	1.9 (1.6)*	1.6 (1.8)	1.8 (1.6)*	1.6 (1.7)*
Chronic diseases at age 70-71 (0-8)	3.3 (2.2)	2.9 (2.0)*	3.3 (2.1)	3.1 (2.4)	3.4 (2.1)	3.2 (2.2)
Multimorbidity at age 60-61 (%)	42.8	37.2*	50.7*	38.0*	50.4*	40.5
Multimorbidity at age 70-71 (%)	78.2	73.3*	79.9	70.7*	79.7	75.4
Earlier-life disadvantages						
Parental education: < 8 years (%)	21.4	15.0*	21.9	21.1*	33.4*	19.4*
Parental education: 8 years (%)	17.9	18.1*	18.9*	16.3*	19.0*	19.6*
Parental education: > 8 years (%)	60.7	66.9*	59.1	62.6*	47.6*	61.0*
Allostatic load (z-score, -1.7, 2.1)	0.1 (0.5)	0.3 (0.5)*	0.0 (0.5)	0.1 (0.5)*	-0.2 (0.5)*	-0.6 (0.4)*
Childhood traumas (0-7)	1.5 (1.2)	1.5 (1.2)*	1.6 (1.2)*	1.6 (1.3)*	1.4 (1.2)*	1.5 (1.3)*
Sociodemographics						
Gender: Female (%)	44.5	42.6	55.6*	36.2*	94.9*	78.2*
Race: White non-Hispanic (%)	72.0	79.2*	73.6	71.3*	65.0*	77.1*
Race: Black non-Hispanic (%)	16.3	13.7*	17.1	14.5*	12.5*	12.7*
Race: Other non-Hispanic (%)	2.1	1.8	1.8	2.4*	2.2*	3.0*
Race: Hispanic (%)	9.6	5.3*	7.5*	11.8*	20.3*	7.3*
Education: < 12 years (%)	24.5	16.0*	28.0*	23.5	43.4*	23.1
Education: 12 years (%)	36.0	36.0	37.5	33.2*	37.6	36.0*
Education: > 12 years (%)	39.6	48.0*	34.6*	43.4*	19.1*	40.9*
Occupation: Never worked (%)	0.0	0.0	1.2*	0.0	19.4*	0.0
Occupation: White-collar (%)	31.5	39.4*	25.9*	33.5	9.9*	25.4*
Occupation: Pink-collar (%)	34.4	35.0	38.8*	36.3	53.5*	56.2*
Occupation: Blue-collar (%)	34.1	25.6*	34.1	30.2*	17.1*	18.5*
Time-varying health covariates						
Self-reported health (1-5)	3.2 (1.1)	3.45 (1.0)*	3.0 (1.1)*	3.4 (1.1)*	2.9 (1.2)*	3.4 (1.1)*
Depressive symptoms (0-8)	6.7 (1.8)	7.05 (1.5)*	6.4 (2.1)*	6.9 (1.7)*	6.0 (2.3)*	6.8 (1.7)*
ADL limitations (0-10)	9.1 (1.4)	9.25 (1.2)*	8.6 (1.9)*	9.3 (1.3)*	8.4 (2.2)*	9.1 (1.4)
BMI: Underweight (%)	1.3	0.9	1.5*	1.5*	2.8*	1.7*
BMI: Normal (%)	27.7	29.7*	30.0*	29.5*	32.8*	35.9*
BMI: Overweight (%)	42.9	42.3	38.8*	41.2*	31.8*	38.7*
BMI: Obese (%)	28.1	27.2	29.7*	27.8*	32.7*	23.8*
Drinking: Abstainer (%)	48.8	40.9*	51.6*	47.7	69.7*	52.8*
Drinking: Soft (<1/day, %)	38.5	44.1*	35.5*	38.6	24.8*	38.1*
Drinking: Moderate (1-2/day, %)	9.3	11.0*	9.0	10.7*	4.2*	7.3*
Drinking: Heavy (3+day, %)	3.4	4.0	3.9	3.0*	1.2*	1.9*
Smoking: Never (%)	34.8	38.8*	35.3	37.7*	48.1*	45.1*
Smoking: Ever (%)	40.0	41.6	40.3	37.1*	26.7*	28.3*
Smoking: Current (%)	25.2	19.7*	24.4	25.2	25.1	26.6

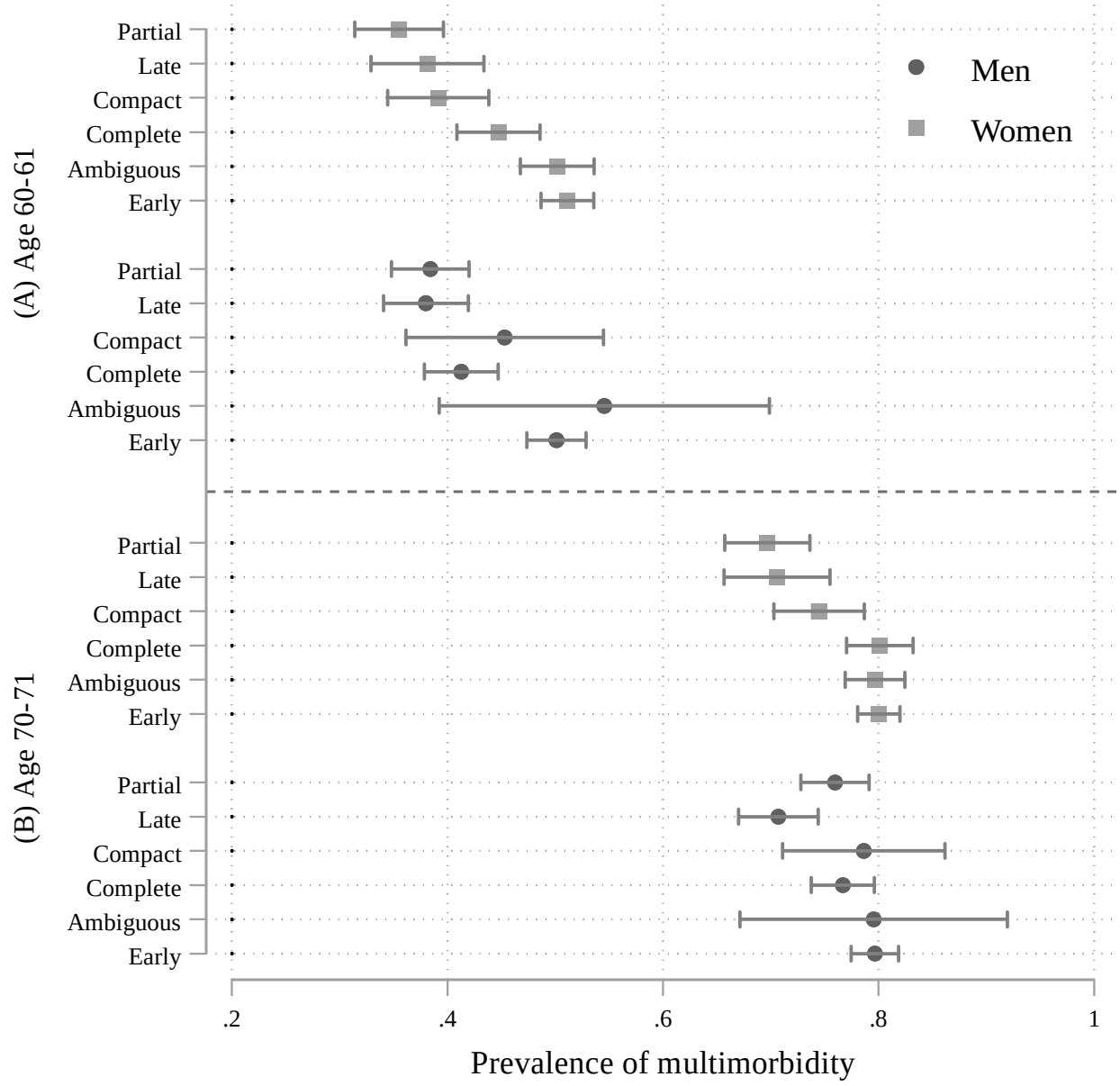
Note: N = 7,880 individuals (4,344 female). Standard errors are reported in parentheses. A star (*) indicates significant differences at p<0.05 relative to *complete*. For time-varying health covariates we report baseline values at age 60-61. Abbreviations: ADL=Activities of Daily Living, BMI=Body Mass Index.

Table 2. Mixed-effects Poisson regression results for the number of chronic diseases

	Model 1		Model 2		Model 3		Men		Women	
	IRR (CI)	*p*	*IRR (CI)*	*p*	*IRR (CI)*	*p*	*IRR (CI)*	*p*	*IRR (CI)*	*p*
Intercept	1.95 (1.91–1.98)	<0.001	1.35 (1.28–1.42)	<0.001	2.14 (1.93–2.37)	<0.001	2.01 (1.73–2.34)	<0.001	2.26 (1.97–2.60)	<0.001
Sequences and age										
Age			1.15 (1.14–1.16)	<0.001	1.14 (1.13–1.15)	<0.001	1.15 (1.13–1.16)	<0.001	1.13 (1.12–1.14)	<0.001
Sequence: Partial			0.87 (0.80–0.93)	<0.001	0.92 (0.86–0.99)	0.022	0.96 (0.87–1.05)	0.365	0.88 (0.80–0.97)	0.012
Sequence: Early			1.15 (1.08–1.22)	<0.001	1.09 (1.03–1.15)	0.003	1.13 (1.04–1.22)	0.004	1.04 (0.96–1.12)	0.348
Sequence: Late			0.90 (0.83–0.98)	0.011	0.93 (0.86–1.00)	0.056	1.00 (0.91–1.11)	0.939	0.83 (0.74–0.93)	0.001
Sequence: Ambiguous			1.13 (1.04–1.22)	0.004	1.07 (0.99–1.15)	0.112	1.22 (0.93–1.60)	0.144	0.99 (0.91–1.09)	0.906
Sequence: Compact			0.97 (0.88–1.07)	0.536	1.00 (0.92–1.09)	0.980	1.10 (0.93–1.32)	0.266	0.94 (0.85–1.04)	0.245
Sequence: Partial * Age			1.00 (0.99–1.01)	0.757	1.00 (0.99–1.01)	0.723	1.00 (0.99–1.02)	0.855	1.00 (0.98–1.02)	0.872
Sequence: Early * Age			0.98 (0.97–0.99)	<0.001	0.98 (0.97–0.99)	<0.001	0.98 (0.96–0.99)	0.002	0.98 (0.97–1.00)	0.027
Sequence: Late * Age			0.99 (0.98–1.01)	0.334	0.99 (0.98–1.01)	0.315	0.98 (0.97–1.00)	0.042	1.01 (0.99–1.03)	0.419
Sequence: Ambiguous *Age			0.98 (0.97–0.99)	0.003	0.98 (0.97–1.00)	0.010	0.96 (0.92–1.00)	0.054	0.99 (0.98–1.01)	0.247
Sequence: Compact * Age			0.99 (0.98–1.01)	0.356	0.99 (0.98–1.01)	0.274	0.98 (0.95–1.01)	0.189	1.00 (0.98–1.02)	0.928
Earlier-life advantages										
Parental education: < 8 years					1.01 (0.95–1.07)	0.758	1.01 (0.93–1.11)	0.777	1.00 (0.93–1.07)	0.949
Parental education: > 8 years					1.03 (0.99–1.08)	0.169	1.04 (0.97–1.12)	0.292	1.02 (0.97–1.08)	0.421
Allostatic load (-1.7, 2.1)					1.16 (1.11–1.20)	<0.001	1.16 (1.10–1.24)	<0.001	1.14 (1.09–1.20)	<0.001
Childhood traumas (0-7)					1.08 (1.07–1.10)	<0.001	1.08 (1.06–1.10)	<0.001	1.09 (1.07–1.11)	<0.001
Sociodemographics										
Gender: female					0.98 (0.94–1.02)	0.359				
Race: Black non-Hispanic					1.08 (1.02–1.13)	0.003	1.06 (0.98–1.15)	0.156	1.08 (1.01–1.14)	0.016
Race: Other non-Hispanic					0.99 (0.93–1.05)	0.686	0.93 (0.84–1.03)	0.178	1.02 (0.94–1.11)	0.598
Race: Hispanic					1.01 (0.90–1.14)	0.884	1.07 (0.89–1.29)	0.465	0.95 (0.82–1.11)	0.536
Education: <12 years					0.96 (0.91–1.00)	0.058	1.03 (0.96–1.11)	0.448	0.91 (0.86–0.97)	0.002
Education: >12 years					0.91 (0.86–0.96)	<0.001	0.97 (0.90–1.05)	0.488	0.86 (0.80–0.92)	<0.001
Occupation: Never worked					0.84 (0.76–0.93)	0.001	0.81 (0.57–1.14)	0.227	0.84 (0.76–0.94)	0.002
Occupation: Blue-collar					1.01 (0.96–1.05)	0.797	1.03 (0.96–1.12)	0.405	0.99 (0.94–1.06)	0.865
Occupation: Pink-collar					0.97 (0.93–1.03)	0.333	0.98 (0.92–1.06)	0.659	0.99 (0.91–1.07)	0.807
Time-varying health covariates										
Self-reported health (1-5)					0.89 (0.88–0.90)	<0.001	0.90 (0.89–0.91)	<0.001	0.89 (0.88–0.90)	<0.001
Depressive symptoms (0-8)					0.99 (0.98–0.99)	<0.001	0.99 (0.98–0.99)	<0.001	0.99 (0.99–1.00)	<0.001
ADL limitations (0-10)					0.98 (0.98–0.99)	<0.001	0.98 (0.98–0.99)	<0.001	0.98 (0.98–0.99)	<0.001
BMI: Underweight					1.05 (1.00–1.11)	0.058	1.04 (0.95–1.14)	0.352	1.06 (1.00–1.13)	0.070
BMI: Overweight					1.03 (1.01–1.05)	0.007	0.99 (0.96–1.02)	0.616	1.06 (1.03–1.09)	<0.001
BMI: Obese					1.07 (1.04–1.10)	<0.001	1.02 (0.98–1.07)	0.271	1.11 (1.07–1.16)	<0.001
Drinking: Abstainer					1.07 (1.04–1.11)	<0.001	1.08 (1.03–1.12)	0.001	1.06 (1.01–1.12)	0.032
Drinking: Soft <1/day					1.03 (0.99–1.06)	0.106	1.03 (0.99–1.07)	0.149	1.02 (0.97–1.07)	0.502
Drinking: Heavy 3+/day					1.01 (0.96–1.06)	0.726	0.99 (0.93–1.05)	0.695	1.09 (0.99–1.20)	0.091
Smokes: Ever					0.92 (0.90–0.95)	<0.001	0.88 (0.85–0.91)	<0.001	0.97 (0.93–1.00)	0.056
Smokes: Current					1.13 (1.11–1.16)	<0.001	1.07 (1.03–1.10)	<0.001	1.19 (1.15–1.22)	<0.001
Random Effects and Model Fit										
Var(residual)	0.41		0.41		0.41		0.42		0.41	
Var(individual)	0.66		0.65		0.48		0.53		0.42	
ICC	0.61		0.61		0.53		0.56		0.51	
Marginal R^2 / Conditional R^2	0.000 / 0.613		0.049 / 0.629		0.119 / 0.590		0.106 / 0.605		0.138 / 0.576	

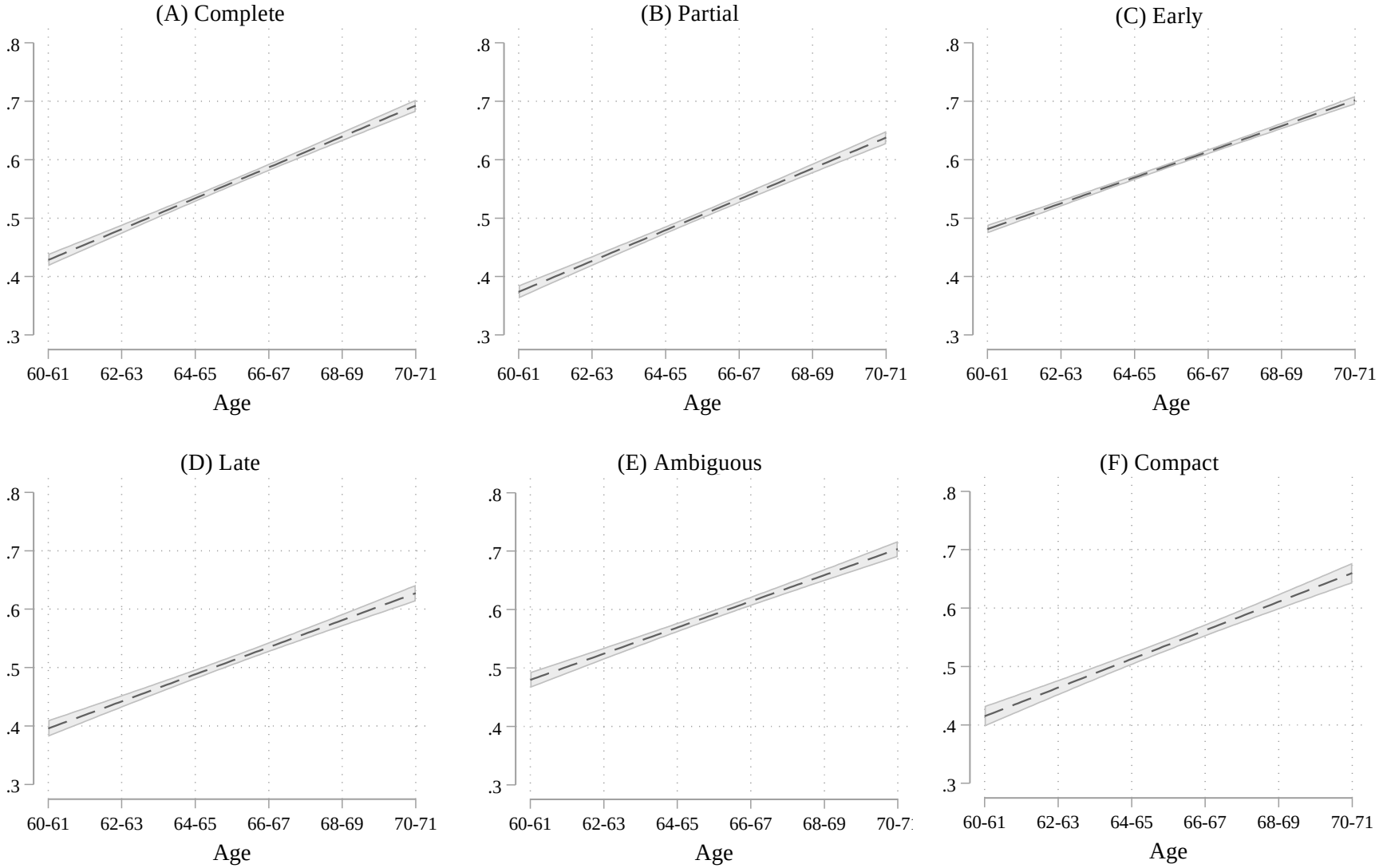
Note: N = 7,880 individuals (4,344 female), 47,280 observations. Mixed-effects Poisson regression Incidence Risk Ratio (IRR) coefficients with 95% confidence intervals (CI) in parentheses. Reference categories are: Sequence: Complete; Race: White non-Hispanic; Education: 12 years; Body Mass Index (BMI): Normal weight; Drinking: Moderate (1-2/day); Smoking: Never; Occupation: White-collar; Parental education: 8 years. Marginal R^2 is the proportion of variance explained by fixed factors. Conditional R^2 is the proportion of variance explained by both the fixed and random factors in the model. Abbreviations: ADL=Activities of Daily Living, BMI=Body Mass Index.

Figure 1. Percentage of people with two or more chronic diseases at ages 60-61 and 70-71, by type of retirement sequence and gender



Note: N = 7,880 individuals (4,344 female). 95% confidence intervals are displayed with brackets. Panels A and B display results at age 60-61 and 70-71, respectively.

Figure 2. Adjusted predicted probabilities of reporting two or more chronic diseases, by retirement sequence and age



Note: N = 7,880 individuals (4,344 female), 47,280 observations. Estimates based on model 3 in Table S1. 95% confidence intervals are displayed with a shaded area. Panels A to F display results for each type of retirement sequence.

SUPPLEMENTAL MATERIAL

Table S1. Research sample and attrition rates

Wave	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Year	**1992**	**1994**	**1996**	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**
Birth cohort	Age of respondents (in years) Attrition rate (% relative to first observed wave)										
1931	61 0.0%	63 1.8%	65 3.8%	67 5.5%	69 7.2%	71 7.6%					
1932	60 0.0%	62 3.0%	64 5.5%	66 4.8%	68 5.4%	70 7.0%					
1933		61 0.0%	63 0.0%	65 1.7%	67 4.0%	69 5.3%	71 7.7%				
1934		60 0.0%	62 0.0%	64 2.2%	66 5.2%	68 5.7%	70 6.5%				
1935			61 0.0%	63 0.0%	65 0.0%	67 2.4%	69 4.3%	71 5.6%			
1936			60 0.0%	62 0.0%	64 0.0%	66 1.7%	68 4.9%	70 6.4%			
1937				61 0.0%	63 0.0%	65 0.0%	67 0.0%	69 2.4%	71 4.7%		
1938				60 0.0%	62 0.0%	64 0.0%	66 0.0%	68 1.8%	70 4.1%		
1939					61 0.0%	63 0.0%	65 0.0%	67 0.0%	69 0.0%	71 2.7%	
1940					60 0.0%	62 0.0%	64 0.0%	66 0.0%	68 0.0%	7 2.3%	
1941						61 0.0%	63 0.0%	65 0.0%	67 0.0%	69 0.0%	71 0.0%

Table S2. Average per patient and total healthcare costs by type of retirement sequence

	By age and 10-years total cost per patient							Population cost		
	60	62	64	66	68	70	Total	%	N	10-year total
Partial	$3.18	$3.58	$3.98	$4.22	$4.60	$5.15	$42.07	15.53	352,622	$14,833,397.05
Late	$3.52	$3.81	$4.02	$4.18	$4.36	$4.78	$41.69	11.68	265,204	$11,056,885.17
Compact	$3.53	$4.01	$4.50	$4.75	$5.13	$5.63	$46.99	6.80	154,400	$7,255,410.40
Complete	$3.58	$3.89	$4.31	$4.44	$4.63	$5.19	$44.11	18.35	416,653	$18,379,813.79
Ambiguous	$3.98	$4.43	$4.73	$4.99	$5.30	$5.76	$49.53	10.98	249,310	$12,348,074.99
Early	$4.01	$4.40	$4.78	$5.20	$5.46	$5.87	$50.50	36.66	832,397	$42,036,880.90

Source: Authors' calculations using previous estimates by Glynn et al. (2011).

Note: Health care costs are reported in 1,000 and include the sum of primary care consultations, hospital outpatient visits, and hospital admissions.

Figure S1: Model predictive performance

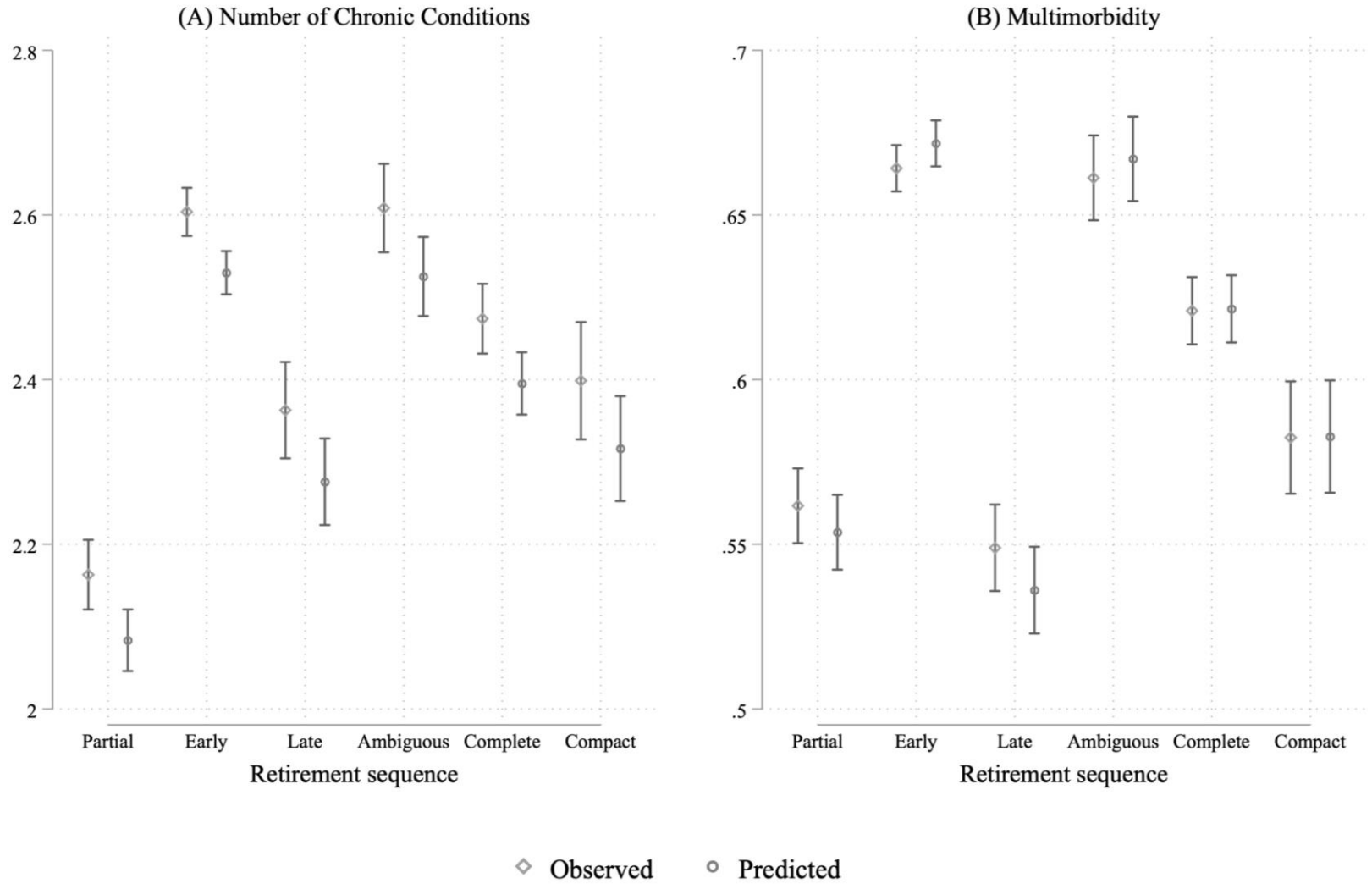
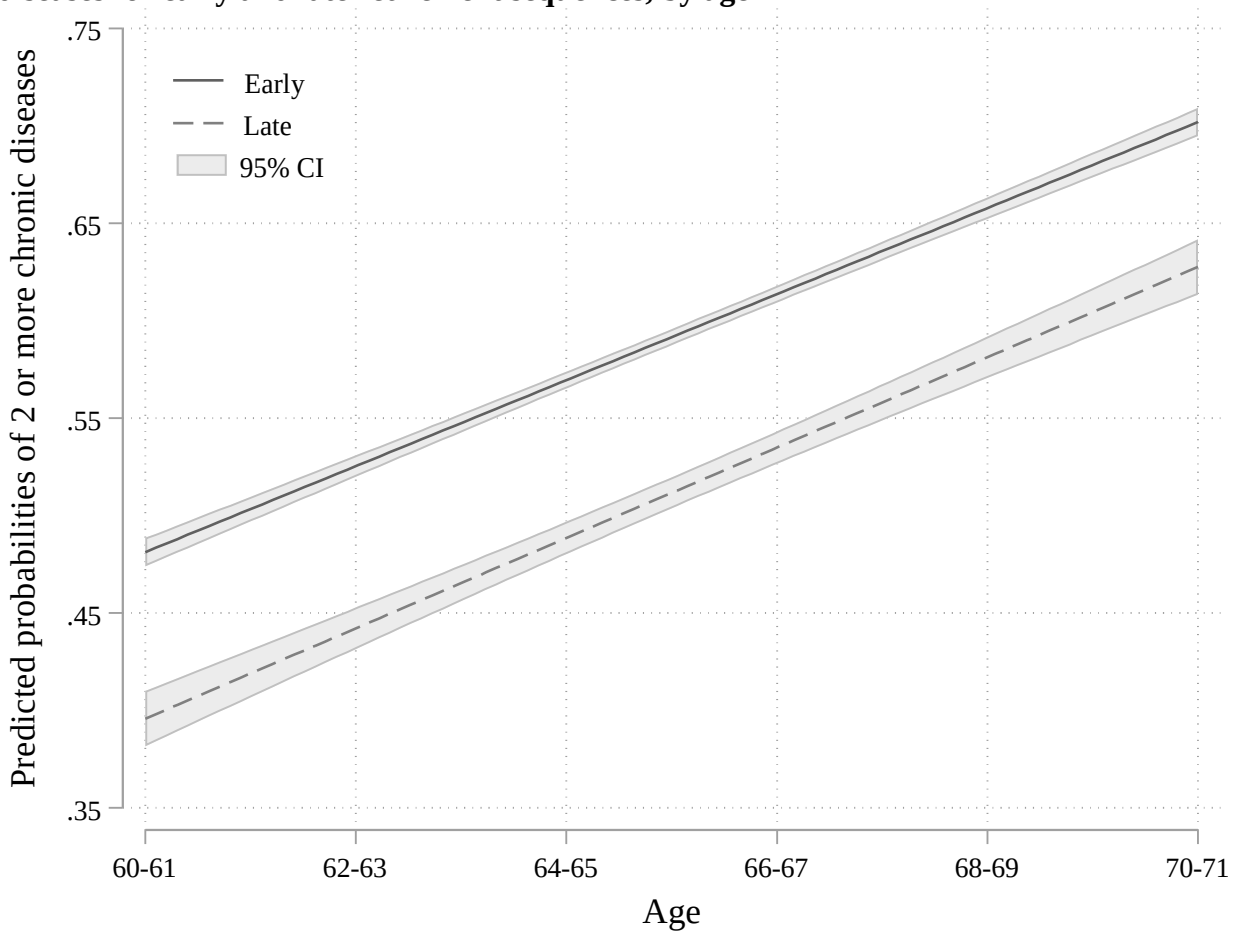


Figure S2. Adjusted predicted probabilities of reporting two or more chronic diseases for early and late retirement sequences, by age



Note: N = 7,880 individuals (4,344 female), 47,280 observations. Estimates based on model 3 in Table 2. 95% confidence intervals are displayed with a shaded area. For the full results see Figure 2.