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The Life Course, Cohort Dynamics, and International Differences in Aging Trajectories

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Abstract In recent years, population health research has focused on understanding the determinants of later-life health. Two strands of that work have focused on (1) international comparisons of later-life health and (2) assessing the early-life origins of disease and disability and the importance of life course processes. However, the less frequently examined intersection of these approaches remains an important frontier. The present study contributes to the integration of these approaches. We use the Health and Retirement Study family of data sets and a cohort dynamic approach to compare functional health trajectories across 12 high-income countries and to examine the role of life course processes and cohort dynamics in contributing to variation in those trajectories. We find substantial international variation in functional health trajectories and an important role of cohort dynamics in generating that variation, with younger cohorts often less healthy at comparable ages than the older cohorts they are replacing. We further find evidence of heterogeneous effects of life course processes on health trajectories. The results have important implications for future trends in morbidity and mortality as well as public policy.

Keywords HRS · SHARE · Life course · Trajectories · Aging vectors

Introduction

Substantial progress has been made in understanding the determinants of later-life health. Two fruitful strands in that effort have (1) leveraged international comparisons

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to examine processes that would otherwise remain obscured in single-population studies and (2) investigated the life course and early-life origins of disease and disability. However, the intersection of these perspectives remains understudied. The present study builds at that intersection by investigating international variation in later-life functional health trajectories and the role of life course processes and cohort dynamics in shaping that variation. We find substantial cross-national variation in aging trajectories and that cohort dynamics are an important contributor to that variation. Trajectories are further influenced by differential exposure to health insults over the life course.

Background

International Differences in Adult Health

Drawing from the social and health sciences, the population health perspective emphasizes understanding what puts any particular individual at risk of disease (*incidence*) and what leads some populations to be healthier than others (*prevalence*), and recognizes that the two may be quite different (Kindig and Stoddart 2003; Rose 2001). Comparative demographic health research has traditionally focused on overall mortality or on infant and child mortality as important structural components of the demographic transition. In recent years, population aging has inspired greater attention to health in later life (Crimmins and Beltrán-Sánchez 2010). These studies have most frequently compared health across high-income contexts in western Europe—often including explicit comparisons with the United States—and have found substantial differences in a variety of health outcomes, including mortality, disability, and chronic disease incidence and prevalence (Avendaño et al. 2005, 2009, 2009; Banks et al. 2006, 2011; Mackenbach et al. 2008; Solé-Auró et al. 2015).

Research has often focused on compositional differences in behavioral, psychosocial, and material risk factors as explanations for international heterogeneity in population health. However, obesity, physical activity, smoking, and social integration appear to play minor roles in generating the current international divergence in chronic disease prevalence and later-life mortality (Alley et al. 2011; Banks et al. 2011, 2012; Preston et al. 2011; Steptoe and Wikman 2011). Other comparative work has explored the influence of institutional forces and welfare state regimes that may be responsible for creating variation in health within and between populations (Bambra 2007; Bergqvist et al. 2013). However, the institutional literature has provided decidedly mixed results, with findings frequently dependent on the specific welfare state typology used or on the specific policies and institutional arrangements considered (Bergqvist et al. 2013). The present study contributes to comparative research by focusing on another, less frequently examined, yet centrally important structural determinant of later-life health: the life course.

Cohorts and the Life Course

The foundational insight of the life course perspective is that the health of individuals at specific points in time must be understood within the context of their cumulative lived

experience. Therefore, any particular observation represents but one point along an emergent trajectory. Furthermore, individual life trajectories must be understood as being embedded in time and place (Elder 1998). Time and place are central life course concepts because they delineate the constellation of opportunities and constraints within which individuals and families make trajectory-altering choices. Acknowledging the centrality of context (time and place) also requires recognizing the importance of cohorts. By definition, cohorts are a product of context, exposing their members to particular arrays of sociohistorical circumstances that shape their life trajectories as they unfold over time.

Unsurprisingly, prior analysis has found substantial cohort influences on trends in population health and mortality. For example, Yang (2008) found that large secular declines in U.S. mortality in the second half of the twentieth century were largely driven by cohort processes. Important for the current study's focus on functional health, Manton et al. (1997) found large increases in survival and in maintaining functional capacity across cohorts born in the nineteenth and twentieth centuries. Recent research has further suggested a strong role for cohort processes in shifting racial inequalities in U.S. mortality (Kramer et al. 2015; Masters et al. 2014).

Although life course research has examined the role of shifting social and economic contexts across cohorts within countries (Elder 1998; Elder et al. 1986; Elder et al. 1984; Holahan and Sears 1995), much less effort has been devoted to cross-national cohort comparisons. Toward that end, the present study adopts a comparative cohort-based trajectory approach. The life course perspective highlights the importance of context in determining variation in individual and cohort risk exposure, while nation states act as essential forces shaping the distribution of those exposures across geographic and temporal space. Those exposures include the local epidemiologic environment and the macro-institutional context that structure social processes essential to the determination of health, such as human capital formation, and the socioeconomic context within which individuals and families make trajectory-altering decisions.

Cohort Dynamics and the Early Origins of Disease

An important aspect of life course research has been to examine the lasting impact that childhood health and social conditions have on adult health. Known as the "early origins of disease" (Blane et al. 2007), this literature suggests that the broad parameters of health trajectories are, in part, forged very early in life: unhealthy and disadvantaged children become unhealthy and disadvantaged adults (Blackwell et al. 2001; Haas 2008; Haas et al. 2011; Kuh et al. 2006). Research on the early origins of disease further provides a set of theoretical perspectives that describe how early life is thought to influence adult health. We suggest that these perspectives can also inform the dynamic mechanisms that contribute to within- and between-country heterogeneity in later-life health trajectories. Specifically, we argue that cohort variation of health emerges, in part, from heterogeneous exposure to risk during developmentally critical or sensitive periods and also from differential risk accumulation over the life course.

The effect that a given event or set of circumstances has on any individual is contingent on its timing within the life course (Elder 1998). The critical/sensitive period perspective posits that health shocks that occur during developmentally critical or sensitive periods can lead to irreversible adaptations in the structure and functioning

of important biological systems (Ben-Shlomo and Kuh 2002), including cardiometabolic processes (Barker 1994), immune function (Cohen et al. 2004; McDade 2005), and inflammatory pathways (Fagundes and Way 2014). Such adaptations may increase survival in the short term but manifest in disease decades later (Barker 1994). At the population level, such processes can also generate cohort variation in health because some cohorts may experience a particular exposure while others do not. Even when different cohorts experience a common exposure, they inevitably do so at different ages and life stages, and with unique sets of prior experience, creating further cohort heterogeneity. A well-documented example of this is the Dutch hunger winter of 1944 in which the timing of *in utero* and childhood exposure to nutritional deprivation had heterogeneous health impacts decades later (Roseboom et al. 2011).

Countries have varied in the timing and progression through the epidemiologic transition, creating variation in exposure to early-life health risks between populations and across cohorts (McEniry 2014; Omran 1971). For example, the infant mortality rate in the United States in the early 1930s was approximately 52 per 1,000 births; the rate was 47 in Switzerland, 66 in the UK, 80 in France, and more than 100 in Italy and Spain (author's calculations using Human Mortality Database data) (HMD n.d.). As discussed later, we find further evidence of substantial international variation in exposure to poor childhood health and early-life socioeconomic disadvantage among the aging cohorts examined here. Given the established effect that childhood health and socioeconomic status (SES) have on functional health trajectories (Haas 2008), this variation is likely to contribute to international differences in such trajectories. Previous work has examined international variation in the effect of early-life health status across contexts. However, this work has not explicitly examined cohort dynamics and has been limited by either examining only a few contexts (Banks et al. 2011) or by using indirect or proxy measures of childhood health such as adult stature, rural place of birth, and aggregate country-level caloric intake during childhood (McEniry 2014; McGovern 2014). International variation in functional health trajectories may also arise from heterogeneous chains of risk or in the differential accumulation of insults across the life course. The accumulation/cumulative insult perspective suggests that social, environmental, and behavioral exposures accumulate over the life course and that it is this lifetime accumulation of risk that is important (Ben-Shlomo and Kuh 2002). Therefore, deleterious exposures in early life may be compounded by subsequent insults or ameliorated by salubrious investments. Countries vary along a number of important institutional dimensions that affect life course accumulation processes, which may create variation in health trajectories both directly and indirectly by modulating the effect of prior exposures. Related to accumulation, the chains-of-risk perspective suggests that early-life factors influence later-life health by structuring subsequent etiologies of risk. For example, childhood SES is thought to pattern risk of adult disease not through its own independent influence but rather as a determinant of socioeconomic attainment, and adult SES is thought to be the central etiologic pathway (Power and Matthews 1997). Thus, early life matters insofar as it initiates chains of risk that cascade throughout the life course.

An example of institutional variation leading to differential accumulation and chains of risk can be found in educational systems. More-egalitarian human capital investment increases adult socioeconomic opportunities and provides both material and psychosocial resources, which improve individual and population health. It further facilitates

intergenerational socioeconomic mobility, which may help to ameliorate the deleterious effects of childhood health insults or socioeconomic disadvantage. Conversely, in societies where access to educational investment is heavily determined by private/familial resources, such opportunities for amelioration are more constrained, and the long-term effect of childhood deprivation may be amplified by subsequent adult disadvantage. Such variation can be seen in our study data. Among the cohorts studied here, 80 % of Spaniards have not completed upper secondary schooling, but only 16 % of Germans failed to do so (author's calculations based on the Survey of Health and Retirement in Europe). The same cohorts in those two contexts faced very different opportunities for human capital accumulation. The more expansive German system provided greater educational opportunity than was afforded in Spain. Therefore, we might expect functional health trajectories to be steeper in Spain than in Germany. Other important institutional factors that shape life course accumulation processes include labor markets, occupational structures, marriage and family formation patterns, and health systems. Previous research has examined life course accumulation processes and their institutional antecedents on health behaviors (Power et al. 2005), as well as trajectories of self-rated health (Sacker et al. 2011). We extend that work by also using a cohort dynamics approach.

We emphasize that even countries that share a number of life course characteristics may still differ along others. For example, as discussed later, aging cohorts in Austria and Switzerland share similar distributions of early-life factors, health behaviors, and educational attainment. However, Austria has a lower proportion married, and the occupational distribution is more heavily skewed toward manual and blue-collar occupations. As a result, the average household income in Austria is less than one-half that in Switzerland. In addition, to the extent that differential shifts exist in the distribution of life course factors across time (such as the expansion of educational attainment), we would also expect there to be varying cohort dynamics across countries. Thus, national context may play an important role in determining how individuals and cohorts experience the life course by (1) structuring exposures during critical/sensitive periods or (2) modulating the long-term effect of these exposures through shifting opportunity structures that provide heterogeneous landscapes of subsequent risk accumulation.

The present study contributes to emerging research at the intersection of the life course and comparative international perspectives. The comparative cohort-based trajectory approach used here provides unique insights into international variation in health trajectories that would not otherwise be possible. It also sheds additional light on the role of life course processes on later-life health. The study achieves this by addressing three goals. First, using aging vector modeling, we identify international variation in the progression of later-life functional limitations. We then examine the role of intercohort dynamics in shaping that cross-national variation. We accomplish this by expressing variation in trajectories as country-specific intercohort trends and formally test whether the cohort dynamics represented in those intercohort trends vary across contexts. Finally, we examine critical period and accumulation processes by estimating the influence of life course factors on health trajectories and whether that influence varies across international contexts.

Methods

Data

We draw on nationally representative samples of men and women aged 50 and older in 12 countries: the United States, England, Austria, Germany, Sweden, the Netherlands, Spain, Italy, France, Denmark, Switzerland, and Belgium. These samples were taken from three longitudinal surveys, enabling us to track the respondents' health over an eight-year period. An important advantage of these surveys for the sake of the current study is that all three surveys collected life course information including childhood health histories and information on parental SES.

Data for the United States come from the Health and Retirement Study (HRS). Begun in 1992, the HRS is a panel study of approximately 28,000 Americans over the age of 50 and born before 1959, designed to investigate the economic and health transitions associated with retirement (Juster and Suzman 1995). It combines extensive information on both socioeconomic and health status. The original data collection took place using in-home face-to-face interviews. Follow-up takes place every second year. Data for England come from the English Longitudinal Study of Ageing (ELSA). Begun in 2002, ELSA is a sample of approximately 11,000 English men and women aged 50 and older and their partners covering the birth cohorts between 1908 and 1956 (Steptoe et al. 2013). Five follow-up waves have been completed at two-year intervals. At Wave 3 (2006–2007), an extensive life history survey was completed, including childhood health histories. Finally, data for the 10 continental European countries are drawn from the Survey of Health, Ageing, and Retirement in Europe (SHARE), which originally sampled 45,000 individuals aged 50 and older from 20 countries. At Wave 3 (2008–2009), the SHARELIFE survey was fielded, collecting extensive life history data, including childhood health histories (Börsch-Supan and Jürges 2005). The structure, content, and target population of ELSA and SHARE were modeled after the HRS with the explicit goal of creating internationally comparable aging data. The resulting strong concordance between the data sets facilitates their integration and comparison. In addition, for a number of the variables of interest, RAND has produced harmonized versions of these data sets. The present study draws on both the raw data as well as the RAND versions.

These surveys have conducted multiple waves of biannual follow-up interviews with different starting years. To ensure comparability in the face of different starting points, we limit our analysis to common periods that yield the highest number of person-year observations. As a result, our study draws from four time points (2004, 2006–2007, 2010–2011, 2012–2013) that are consistent across all surveys. The year 2008 was not included because SHARE did not measure adult health at Wave 3.

We then imposed two further inclusion criteria to create a common set of cohort comparisons. First, the age range of our sample is constrained to be between 50 and 95 at baseline, which means that each country provides a representative sample of men and women born between 1909 and 1954. Second, some of the countries in the SHARE sample had only one or two waves of data. We excluded those countries without at least three waves of observation, leaving us with 10 SHARE countries of 20 for our study. Our final sample includes 67,290 individuals from 12 countries: the United States (N = 20,224), England (N = 6,631), Austria (N = 3,544), Germany (N = 4,583), Sweden (N =

4,278), the Netherlands (N = 3,708), Spain (N = 5,370), Italy (N = 4,175), France (N = 4,202), Denmark (N = 3,205), Switzerland (N = 2,633), and Belgium (N = 4,737).

Measures

Functional Limitation

Functional limitation represents a measure of later-life health status that is of great theoretical and empirical importance. Conceptually, its importance lies in its critical role in connecting disease pathology to disability within the broader disablement process (Nagi 1965, 1991; Verbrugge and Jette 1994). In addition, unlike other measures such as self-rated health, chronic disease diagnosis, and activities of daily living (ADL), it is less subject to bias associated with cultural differences in reporting (Hardy et al. 2014), access to health services, or by social role expectations (Verbrugge and Jette 1994). Because of its important theoretical role in the disablement process, functional limitation is among the most frequently used empirical indicators of later-life health. Focusing on functional limitations further allows our results to be contextualized within the larger empirical literature on aging and disability. This is particularly important given the current study's emphasis on cohorts and the ongoing debate about the compression of morbidity and secular trends in disability (Crimmins and Beltrán-Sánchez 2010; Cutler et al. 2013; Manton et al. 2008). Functional limitation is measured by the sum of eight dichotomous items in which respondents were asked whether they had any difficulty with a series of common physical tasks: walking several blocks, sitting for two hours, getting up from a chair after sitting for a long period, climbing a flight of stairs without resting, lifting or carrying weights more than 10 lb, reaching/extending one's arms above the shoulders, pulling or pushing large objects, and picking up a coin from a table.

Life Course Factors and Other Variables

The assessment of childhood health status is based on retrospective reports. In each study, respondents were asked, "Consider your health while you were growing up, from birth to age 16. Would you say that your health during that time was excellent, very good, good, fair, or poor?" We create a dichotomous measure of poor childhood health that codes those who report experiencing fair or poor childhood health as 1, and those reporting good, very good, or excellent childhood health as 0. Previous research has analyzed the quality of retrospective childhood health histories in large nationally representative samples including the overall subjective childhood health measure used here. The measure has been shown to be reliable, especially when the measure was dichotomized into a good/very good/excellent versus fair/poor comparison, and the quality of measurement did not vary substantially by gender or age (Haas 2007). There is also little evidence that retrospective reports are subject to anchoring, by which current health status contaminates reports of childhood (Haas 2007). In terms of validity, retrospective childhood health has been shown to correlate with birth weight (Haas 2007). Retrospective subjective childhood health status is strongly associated with a wide variety of common childhood conditions and activity limitations (Haas and Bishop 2010).

Educational attainment of both respondent and their parents is standardized using the International Standard Classification of Education (ISCED) with values ranging from 0 (none or pre-primary education) to 7 (advanced professional or doctoral degree). Parental education of the most-educated parent is then dichotomized and takes on a value of 1 if the parent had a primary education or less, and 0 if they had more than a primary education. Childhood socioeconomic conditions are also measured by an indicator of father's occupation and takes on values of 1 if the respondent's father had a professional or managerial occupation, and 0 otherwise.

Respondent's occupation, based on current or last job, was measured using three categories representing low (e.g., manual, blue collar, machine operators, and skilled trades), medium (e.g., white-collar service, sales, clerical, administrative, and military), and high (e.g., professional, managerial, and high level technical) occupational niches. We also include a measure of the total household income, inflation, and currency adjusted to constant 2004 U.S. dollars and adjusted for household size. Because of skew to the income distribution, in the analytic models we use a log transformation (log (household income + $1,000)). We also include an indicator of marital status (1 = married; 0 = not married). To capture behavioral determinants of the disablement process, we include indicators of whether the respondent had ever been diagnosed with any chronic condition (1 = yes; 0 = no), was a current smoker (1 = yes; 0 = no), or was a former smoker (1 = yes; 0 = no). Finally, we include a continuous measure of body mass index (BMI). Central to the estimation of the aging vector models, we include linear and quadratic measures of age (baseline mean-centered). We also include an indicator of gender (1 = female).

Descriptive statistics for each country are presented in Table 1. The United States has the highest average initial level of functional limitations (1.68), and Switzerland has the lowest (0.54). The United States also experienced the largest increase, on average, between Time 1 and Time 4. A major reason for the higher levels of functional limitation in the United States is likely due to the fact that the United States is the oldest sample by at least three years. The United States also has a very high proportion with at least one chronic disease (83 %), whereas only 42 % of the Swiss sample has been diagnosed with a chronic condition.

Statistical Analysis

To implement a comparative cohort-based trajectory approach, the analysis uses an aging vector model to estimate trajectories of functional limitations (Mirowsky and Kim 2007). Aging vector models are a class of multilevel latent curve models in which latent intercepts (baseline level) and slopes (rate of change) are derived from longitudinally observed moments. The within-individual model for functional limitations Y for individual i is expressed as a linear function of time t:

$$Y_{it} = a_{i0} + a_{i1}t + e_{it}, \quad (1)$$

where a_{i0} represents the individual intercept, a_{i1} represents the individual slope, and e_{it} represents the individual and time-specific error. Individual intercepts and slopes can then be expressed as a function of age at baseline (A_i) centered on the mean age at

Table 1 Descriptive statistics by country: Means (with standard deviations in parentheses) and percentages

	United States	England	Austria	Germany	Denmark	Sweden
Age	67.8 (10.6)	64.6 (9.8)	62.6 (8.4)	62.0 (8.3)	62.2 (8.9)	62.7 (8.5)
Female (%)	57.5	55.3	57.1	51.2	52.5	52.3
Married (%)	63.0	55.9	61.6	77.8	68.6	70.3
Poor Childhood Health (%)	6.4	11.7	12.7	14.2	7.4	9.7
Father Professional/Managerial Occupation (%)	14.1	25.3	11.0	13.1	15.6	19.7
Low Parental Education (%)	50.0	87.7	40.7	22.0	46.1	81.0
Occupation (%)						
Low	28.6	33.7	36.8	33.3	27.1	21.8
Medium	41.1	54.0	48.9	49.4	52.7	43.9
High	30.3	12.3	14.3	17.3	20.3	34.3
Household Income ($)	34,744 (60,334)	23,133 (24,299)	22,964 (20,706)	31,667 (39,005)	37,681 (33,188)	36,654 (32,996)
Education (ISCED)	3.0 (1.2)	2.1 (2.0)	3.2 (1.4)	3.4 (1.1)	3.4 (1.4)	3.0 (1.6)
Any Chronic Condition (%)	82.7	70.4	52.0	52.7	56.2	47.1
Smoking (%)						
Current	14.5	14.0	19.7	23.9	28.2	18.5
Former	42.9	48.1	22.6	47.0	44.7	51.6
BMI	27.2 (5.1)	27.5 (5.9)	26.5 (5.9)	26.4 (5.2)	25.5 (4.9)	25.6 (4.9)
Functional Limitations Time 1	1.68 (1.90)	1.41 (1.91)	1.02 (1.52)	0.89 (1.40)	0.72 (1.34)	0.63 (1.22)
Functional Limitations Time 2	1.84 (1.84)	1.44 (1.96)	1.27 (1.77)	0.96 (1.61)	0.66 (1.29)	0.71 (1.28)
Functional Limitations Time 3	2.07 (2.11)	1.57 (2.06)	1.18 (1.73)	1.27 (1.86)	0.77 (1.46)	0.84 (1.53)
Functional Limitations Time 4	2.20 (2.24)	1.62 (2.10)	1.33 (1.95)	1.17 (1.80)	0.85 (1.51)	0.76 (1.39)

Table 1 (continued)

	Spain	Italy	Switzerland	France	Netherlands	Belgium
Age	64.1 (9.3)	62.9 (8.3)	62.8 (8.8)	63.3 (9.4)	61.8 (8.4)	63.1 (9.4)
Female (%)	52.7	52.6	53.0	55.8	52.3	43.5
Married (%)	78.4	81.3	70.0	64.2	78.7	65.8
Poor Childhood Health (%)	7.1	6.5	10.8	9.4	10.6	8.7
Father Professional/Managerial Occupation (%)	7.0	5.5	17.2	16.5	19.3	13.6
Low Parental Education (%)	95.4	95.0	42.5	82.2	80.8	75.2
Occupation (%)						
Low	68.4	47.1	22.6	39.2	23.9	34.7
Medium	23.8	44.1	60.4	44.6	47.2	39.0
High	7.8	8.8	17.0	16.2	28.9	26.3
Household Income ($)	14,142 (21,250)	16,810 (22,300)	50,240 (43,091)	25,006 (26,106)	30,336 (29,536)	31,127 (48,874)
Education (ISCED)	1.4 (1.4)	1.8 (1.3)	3.1 (1.1)	2.4 (1.7)	2.9 (1.4)	2.9 (1.6)
Any Chronic Condition (%)	60.4	60.3	41.9	59.9	44.4	55.6
Smoking (%)						
Current	17.5	22.0	21.1	14.7	22.6	19.1
Former	34.1	31.5	29.9	31.4	49.0	35.7
BMI	25.4 (8.6)	26.1 (5.6)	24.7 (5.5)	25.3 (6.2)	25.6 (5.8)	25.6 (6.1)
Functional Limitations Time 1	1.52 (1.98)	1.09 (1.64)	0.54 (1.04)	0.94 (1.48)	0.72 (1.32)	0.93 (1.51)
Functional Limitations Time 2	1.50 (2.04)	1.28 (1.84)	0.56 (1.15)	1.02 (1.64)	0.70 (1.37)	1.05 (1.64)
Functional Limitations Time 3	1.87 (2.33)	1.54 (2.06)	0.61 (1.19)	1.24 (1.24)	0.84 (1.46)	1.29 (1.75)
Functional Limitations Time 4	1.71 (2.26)	1.50 (2.09)	0.61 (1.21)	1.30 (1.84)	0.91 (1.56)	1.37 (1.86)

baseline (k), a vector of covariates $\mathbf{X}$ (in the case of conditional models), and individual random effects (u_{i0} and u_{i1}):

$$a_{i0} = a_{00} + a_{01}(A_{i0} - k) + a_{02}(A_{i0} - k)^2 + \boldsymbol{\beta}\mathbf{X} + u_i 0 \tag{2}$$

$$a_{i1} = a_{10} + a_{11}(A_{i0} - k) + \boldsymbol{\beta}\mathbf{X} + u_{i1}. \tag{3}$$

Age (A_{it}) for individual i at time t is defined as the difference between the calendar year of the survey S_t and i's birth year B_i reflecting the age-period-cohort triad.

$$A_{it} = S_t - B_i. \tag{4}$$

The aging vector model has a number of characteristics that distinguish it from more common applications of latent curve models. Perhaps most important is that the within-individual model (Eq. 1) estimates change as a function of time (t) rather than age (A_i). Age appears only in the between-individual Eqs. (2) and (3). In a longitudinal study of multiple birth cohorts observed at overlapping or adjacent ages, this modeling strategy allows each individual-year birth cohort to have its own unique trajectory parameters rather than averaging across the experiences of multiple cohorts observed at a common set of ages. Empirically, this frees the cohort-specific aging trajectories from the functional form observed in the cross-sectional age curve (synthetic cohort) (Mirowsky and Kim 2007) so that we can observe the direction and rate of change in aging trajectories across cohorts.

To add the comparative perspective, the aging vector approach is extended to include between-country variation by estimating the within-individual Eq. (1) and the between-individual Eqs. (2) and (3) separately for each country in a multigroup framework. This incorporation of comparative analysis into the aging vector model framework should make intuitive sense from an epidemiological perspective. In this approach, between-individual variation of functional limitations is simultaneously analyzed in terms of prevalence and incidence. Age-specific prevalence risk is derived from Eq. (2), based on cross-sectional differences over age. Incident risk associated with a year increase in age for a given cohort, on the other hand, is expressed in Eq. (3). Intercohort trends are essentially based on the gap between prevalence and incident risks for a given age. Thus, when applied to comparative analysis, aging vector models enable us to illustrate country-specific cohort dynamics that cannot be simply reduced to incidence/prevalence risk factors alone. The model is estimated using Mplus with the full information maximum likelihood estimator, which accounts for sample attrition while using all available observations.

Results

For the first step of the analysis, we constructed a fully free, unconditional multigroup aging vector model of functional limitation trajectories allowing each country-specific cohort to have its own trajectory parameters. Figure 1 presents predicted country-specific aging vector graphs based on the unconditional model. For clarity, we present only every fifth birth cohort. The visualization of the aging vectors shows (1) cross-

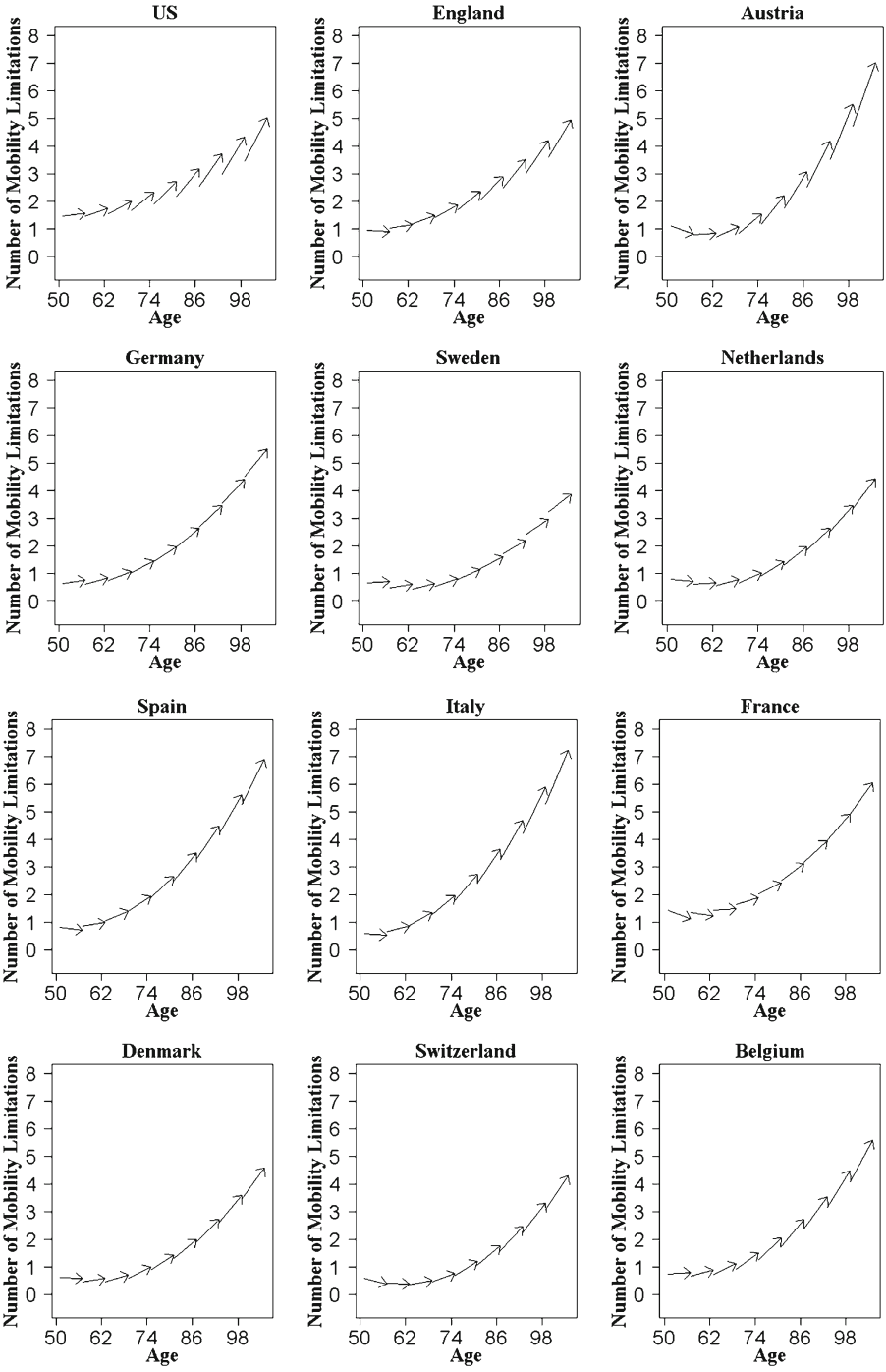

Fig. 1 Aging vector graphs of functional limitations, by country

sectional synthetic cohort curves connecting the bases of vectors and (2) cohort-specific aging trajectories that are differentiated by the moving age-specific mean that each cohort experiences. Taking these two findings together, we can investigate between-country differences in cohort dynamics that cross-sectional analysis alone cannot reveal. The comparisons of synthetic cohort curves show that a few countries have comparatively shallow curves, especially among the younger ages. This group includes Sweden, the Netherlands, Denmark, and Switzerland. Another group of countries, including Austria, Spain, and Italy, have noticeably steeper trajectories. The cohort-specific aging vectors were also suggestive of significant intercohort trends underlying the synthetic cohort trajectories. For several countries, including the Netherlands, Germany, Switzerland, and Denmark, the aging vectors achieved near perfect convergence as a single parabolic trajectory as the tail of each cohort's trajectory lines up with the head of the trajectory of the preceding cohort. Thus, their aging vectors imply little cohort difference in long-term trajectories over the later life course. For other countries—such as England, Austria, Italy, and especially the United States—there were distinctly different trajectories across birth cohorts, as evidenced by the overlap of the head and base of the trajectory arrows between adjacent cohorts, in which more-recent aging cohorts appear to be worse off than their older peers were at the same ages. France and Sweden exhibited intercohort trends in which older cohorts are being replaced by cohorts with lower and flatter trajectories of functional impairment accumulation than their predecessors. However, in Sweden, the most recent cohorts appear to be experiencing elevated functional impairment relative to older cohorts, suggesting a reversal of trend.

We next conducted formal tests to confirm the vector differences between countries suggested in Fig. 1. The results of that analysis are presented in Table 2. The first row presents the model fit statistics for the unconstrained unconditional aging vector model discussed earlier. Based on a variety of model fit indices, the model fits the data well. In Model 2, we impose an equality constraint on the vector intercepts. This forces each country to have the same mean intercept (i.e., same mean number of limitations at baseline averaged across all cohorts). Although this model is more parsimonious, this comes at the expense of a substantial decline in model fit based on all measures of fit, including a large and significant increase in the χ^2. In Model 3, we again took the unconstrained model and imposed an equality constraint on the slopes, forcing each country to have the same mean vector slope (averaging across cohorts). This also

Table 2 Model comparison

Model	*df*	χ^2	$\Delta\chi^2$	AIC	BIC	CFI	TLI	RMSEA
1. Unconstrained Model	120	544.3	–	643,887	644,852	0.990	0.986	0.023
2. Equality of Mean of Vector Intercepts	131	2,098.5	1,554.2***	646,302	647,515	0.954	0.941	0.066
3. Equality of Mean of Vector Slopes	131	764.2	219.9***	644,276	645,489	0.985	0.981	0.029
4. Equality of Age and Age Squared Effect on Intercept	142	931.7	387.4***	644,488	645,600	0.982	0.978	0.032
5. Equality of Age Effect on Slope	131	594.4	50.1***	644,043	645,255	0.989	0.986	0.025

***$p < .001$

resulted in a substantial decline in model fit. Model 4 constrained the effects of age (linear and quadratic) on the intercept to be equal across countries, forcing cohort-specific baseline functional limitations to be invariant across countries. Similarly, in Model 5, we constrained the effect of age on the slope to be invariant across country contexts. The constraints imposed in Models 4 and 5 resulted in large and significant declines in model fit. Overall, the results presented in Table 2 provide strong evidence for substantial international variation in the accumulation of functional limitation over time and across cohorts.

Although the unconditional model suggests substantial variation in trajectories across countries and cohorts, this may reflect compositional differences rather than cohort dynamics per se. To test this, we estimated a conditional multigroup aging vector model that adjusts the latent intercept and slope by a set of covariates over the life course. We estimated the coefficients for covariates separately for each country. Substantively, this conditioning of aging vectors is meaningful in two ways. First, the distribution of observed risk factors for baseline limitation (Eq. (2)) and additional accumulation (Eq. (3)) is standardized. Second, by letting the coefficients vary internationally, we also took into account differential effects of each covariate on trajectories. In doing so, we were able to investigate the cohort process of functional decline that highlights uniqueness embedded in time and place and in the individual life course.

Examining the impact of life course factors on functional health trajectories (Table 3), we found that in all countries, women reported more functional limitations at baseline than men. However, the magnitude varied across countries, with the gender disparity in baseline limitations being smallest in Austria (0.28), Switzerland (0.37), and Germany (0.40), and largest in Italy (0.72) and Spain (0.82). Evidence for the impact of childhood conditions was mixed. In all countries save Switzerland, the experience of poor childhood health was associated with an increase in the baseline level of functional limitation. The magnitude of the deleterious impact of poor childhood health also varied across countries. Except for the nonsignificant effect in Switzerland, the smallest increase in baseline functional limitations associated with poor childhood health was observed for France (0.36), and the largest was observed for Denmark (0.66). These differences were confirmed through formal testing of parameters across countries (see appendix). Importantly, this association also held net of childhood and adult socioeconomic conditions and adult health factors. In only three countries (England, Belgium, and Switzerland) was childhood health significantly associated with a faster rate of subsequent accumulation of functional limitations. Having a father with a professional occupation was not associated with baseline limitations in any country, although among the Swiss, having a high-status father was associated with a more rapid accumulation of functional limitations. Only in the United States was parental education associated with functional health trajectories net of other factors.

Evidence for the effect of marital status was mixed. Being married was associated with fewer limitations at baseline in 5 of the 12 countries but was associated with flatter trajectories (slopes) in only 3 (United States, Denmark, and Italy). With the exception of France, the Netherlands, Switzerland, and Belgium, we observed significant educational gradients in functional limitation trajectories. As with gender and childhood health, the magnitude of educational disparities was quite varied across international contexts. For example, the marginal decrease in initial functional limitation associated with a one-unit increase in educational attainment (based on the ISCED) was more than twice as large in Austria (–0.14) as in Sweden (–0.06). Only in a minority of countries was adult occupation

Table 3 FIML estimates from aging-vector model of functional limitations

	United States				England			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.005	0.00**	0.005	0.00***	0.014	0.00***	0.005	0.00***
Age Squared	0.001	0.00***			0.001	0.00***		
Female	0.477	0.03***	0.000	0.00	0.504	0.04***	0.001	0.01
Poor Childhood Health	0.384	0.05***	0.011	0.01	0.530	0.07***	0.018	0.01*
Father Professional Occupation	−0.027	0.04	0.002	0.01	−0.010	0.05	0.009	0.01
Low Parental Education	0.112	0.04**	0.012	0.01	0.083	0.06	0.006	0.01
Married	−0.089	0.03**	−0.017	0.00***	−0.181	0.04***	−0.007	0.01
Education (ISCED)	−0.072	0.01***	−0.006	0.00**	−0.079	0.02***	0.002	0.00
Occupation Medium	−0.014	0.04	−0.003	0.01	−0.150	0.05**	−0.011	0.01
Occupation High	−0.083	0.04*	−0.008	0.01	−0.335	0.07***	−0.014	0.01
Household Income (ln $)	−0.324	0.02***	−0.001	0.00	−0.141	0.04***	−0.001	0.01
Any Chronic Condition	0.930	0.03***	0.000	0.01	0.983	0.04***	−0.005	0.01
BMI	0.051	0.00***	0.001	0.00**	0.011	0.01	0.001	0.00*
Current Smoker	0.407	0.04***	0.031	0.01***	0.487	0.07***	0.039	0.01***
Former Smoker	0.166	0.03***	−0.002	0.00	0.209	0.04***	0.000	0.01
	Austria				Germany			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.006	0.01	0.010	0.00***	0.030	0.01***	0.004	0.00***
Age Squared	0.003	0.00***			0.002	0.00***		
Female	0.284	0.09**	0.011	0.01	0.395	0.07***	0.001	0.01
Poor Childhood Health	0.383	0.15*	0.007	0.02	0.491	0.11***	−0.008	0.02
Father Professional Occupation	0.142	0.10	−0.018	0.02	0.036	0.07	0.012	0.01
Low Parental Education	0.049	0.11	0.001	0.02	0.054	0.11	0.002	0.02
Married	−0.166	0.10	−0.006	0.02	−0.078	0.09	−0.002	0.02

Table 3 (continued)

Education (ISCED)	−0.141	0.04***	−0.003	0.01	−0.059	0.04*	−0.005	0.01
Occupation Medium	−0.095	0.11	−0.009	0.02	0.058	0.09	−0.037	0.01**
Occupation High	−0.208	0.15	0.013	0.02	0.037	0.12	−0.028	0.02
Household Income (ln $)	0.137	0.06**	−0.029	0.01**	−0.135	0.04**	0.010	0.01
Any Chronic Condition	0.592	0.09***	−0.033	0.02	0.498	0.08***	−0.012	0.01
BMI	0.051	0.01***	0.003	0.00	0.030	0.01***	0.004	0.00*
Current Smoker	0.157	0.12	0.026	0.02	0.341	0.11**	−0.014	0.02
Former Smoker	0.230	0.11*	−0.008	0.02	0.006	0.07	−0.007	0.01
	Spain				Italy			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.031	0.01***	0.008	0.00***	0.050	0.00***	0.006	0.00***
Age Squared	0.002	0.00***			0.002	0.00***		
Female	0.819	0.08***	−0.009	0.01	0.718	0.06***	0.009	0.01
Poor Childhood Health	0.479	0.14***	0.029	0.02	0.549	0.13***	−0.007	0.02
Father Professional Occupation	−0.049	0.12	0.000	0.02	0.146	0.07	−0.014	0.01
Low Parental Education	0.140	0.19	−0.021	0.03	0.008	0.15	−0.006	0.02
Married	−0.018	0.10	−0.021	0.02	0.071	0.08	−0.032	0.01**
Education (ISCED)	−0.136	0.04**	0.007	0.01	−0.072	0.03***	−0.004	0.00
Occupation Medium	−0.288	0.12**	0.015	0.02	−0.041	0.08	−0.015	0.01
Occupation High	0.149	0.18	−0.043	0.03	0.032	0.13	−0.002	0.02
Household Income (ln $)	−0.142	0.05**	0.020	0.01*	−0.052	0.04	−0.004	0.01
Any Chronic Condition	0.834	0.09***	−0.041	0.02**	0.646	0.07***	−0.005	0.01

Table 3 (continued)

BMI	0.049	0.01***	0.001	0.00	0.050	0.01**	0.001	0.00
Current Smoker	−0.089	0.10	−0.001	0.02	0.097	0.08	−0.004	0.01
Former Smoker	0.137	0.10	−0.041	0.02**	−0.030	0.07	−0.010	0.01
	France				Denmark			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.022	0.00***	0.006	0.00***	0.006	0.00	0.004	0.00***
Age Squared	0.003	0.00***			0.002	0.00***		
Female	0.540	0.06***	0.008	0.01	0.420	0.06***	−0.018	0.01*
Poor Childhood Health	0.355	0.10***	0.009	0.02	0.656	0.14***	−0.011	0.02
Father Professional Occupation	−0.003	0.09	0.014	0.01	−0.030	0.06	0.008	0.01
Low Parental Education	0.039	0.09	0.003	0.01	0.062	0.07	−0.013	0.01
Married	−0.077	0.06	0.000	0.01	−0.063	0.07	−0.033	0.01**
Education (ISCED)	0.016	0.02	0.002	0.00	−0.066	0.02**	−0.003	0.00
Occupation Medium	−0.229	0.08**	0.007	0.01	−0.102	0.08	−0.005	0.01
Occupation High	−0.406	0.10***	0.012	0.02	−0.205	0.09*	0.012	0.01
Household Income (ln $)	−0.111	0.04**	−0.005	0.01	−0.076	0.05	−0.003	0.01
Any Chronic Condition	0.619	0.06***	−0.004	0.01	0.487	0.06***	−0.011	0.01
BMI	0.054	0.00***	0.002	0.00*	0.025	0.01**	0.001	0.00
Current Smoker	0.104	0.07	0.019	0.01	0.392	0.07***	0.002	0.01
Former Smoker	0.027	0.07	0.003	0.01	0.091	0.06	0.002	0.01

Table 3 (continued)

	Sweden				Netherlands			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.005	0.00	0.005	0.00***	0.003	0.00	0.004	0.00***
Age Squared	0.002	0.00***			0.002	0.00***		
Female	0.457	0.04***	−0.016	0.01*	0.452	0.05***	0.001	0.01
Poor Childhood Health	0.405	0.11***	0.007	0.02	0.569	0.11***	−0.021	0.02
Father Professional Occupation	−0.037	0.06	0.009	0.01	−0.077	0.06	0.004	0.01
Low Parental Education	0.089	0.07	−0.027	0.01**	0.004	0.09	0.009	0.01
Married	−0.122	0.06*	−0.005	0.01	−0.284	0.08***	0.002	0.01
Education (ISCED)	−0.060	0.02**	0.006	0.00	−0.020	0.03	−0.005	0.00
Occupation Medium	0.072	0.08	−0.025	0.01*	−0.056	0.08	−0.001	0.01
Occupation High	−0.059	0.08	−0.033	0.01**	−0.159	0.08	0.012	0.01
Household Income (ln $)	−0.097	0.04*	0.010	0.01	−0.088	0.04*	0.005	0.01
Any Chronic Condition	0.029	0.05	0.007	0.01	0.399	0.06***	0.000	0.01
BMI	0.011	0.01***	0.001	0.00	0.050	0.01***	0.001	0.00
Current Smoker	0.256	0.07***	0.013	0.01	0.174	0.07**	0.026	0.01*
Former Smoker	0.154	0.05**	−0.009	0.01	0.129	0.06*	−0.010	0.01
	Switzerland				Belgium			
	Intercept	SE	Slope	SE	Intercept	SE	Slope	SE
Age	0.002	0.00	0.005	0.00***	0.017	0.00***	0.006	0.00***
Age Squared	0.002	0.00***			0.002	0.00***		

Table 3 (continued)

Female	0.372	0.06***	−0.018	0.01*	0.568	0.05***	0.014	0.01
Poor Childhood Health	0.087	0.12	0.046	0.02**	0.396	0.11***	0.034	0.02*
Father Professional Occupation	−0.144	0.07	0.034	0.01**	0.043	0.08	−0.007	0.01
Low Parental Education	−0.004	0.08	0.001	0.01	−0.003	0.08	0.006	0.01
Married	−0.085	0.07	0.000	0.01	−0.149	0.06*	−0.001	0.01
Education (ISCED)	−0.018	0.03	−0.003	0.00	−0.040	0.02	−0.007	0.00
Occupation Medium	−0.095	0.10	0.010	0.02	−0.057	0.08	0.003	0.01
Occupation High	−0.030	0.13	−0.011	0.02	−0.089	0.09	0.001	0.01
Household Income (ln $)	−0.045	0.04	0.005	0.01	−0.143	0.03***	0.011	0.01*
Any Chronic Condition	0.368	0.08***	−0.017	0.01	0.578	0.05***	−0.013	0.01
BMI	0.019	0.01*	0.003	0.00	0.032	0.00***	0.003	0.00*
Current Smoker	0.185	0.08*	−0.002	0.01	0.203	0.07**	0.031	0.01**
Former Smoker	0.100	0.07	−0.016	0.01	0.124	0.06*	−0.005	0.01

*$p < .05$; **$p < .01$; ***$p < .001$

associated with functional health trajectories net of other factors. Household income was associated with later-life functional limitations in all countries except Switzerland, Denmark, and Italy. Again, we found large differences in the effect of income on functional limitations. A 10 % increase in income was associated with 0.03 fewer baseline limitations in the United States; in Sweden, it was associated with only 0.009 fewer limitations. In Austria, higher income was associated with greater baseline limitations.

Evidence for the effect of BMI on trajectories was consistent with a significant positive association observed in all countries. The presence of chronic health conditions is an important determinant of the onset of the disablement process. Accordingly, we observed a significant effect of having any chronic health condition on the initial level of functional limitation, although it was generally not associated with variation in the slope. As with poor childhood health, adult chronic conditions appeared to be more consequential for functional health in some countries than in others. For example, among the Swiss, the presence of a chronic health condition was associated with 0.37 additional limitations at baseline; among older English and Americans, it was nearly a full limitation more (0.98 and 0.93, respectively). This may be due to differences in the distributions of chronic disease in question and the relative effect each has on functional impairment. In all but two countries (France and Italy), smoking (current and/or former) was associated with either higher initial levels of functional limitation or greater accumulation over time. We conducted formal tests of all model coefficients across countries. These results are presented in Table 5 of the appendix.

Finally, we return our attention to intercohort trends under the conditional model. To further quantify and compare intercohort trends across countries, we focus on a mathematical entity called the *trend function* (Kim 2008; Mirowsky and Kim 2007). The trend function T_i is calculated by first taking the derivative of the individual intercept (Eq. (2)) over baseline age A_{i0}, and then subtracting it from the individual slope (Eq. (3)).

$$T_i = \hat{a}_{i1} - \frac{d\hat{a}_{i0}}{dA_{i0}}. \tag{5}$$

The trend function represents the extent to which within-individual change per year for a given cohort differs from the cross-sectional difference associated with one-year increase in age. Thus, a negative trend function indicates that more recent cohorts tend to report fewer age-specific limitations than those who came before them, while a positive trend function indicates that more recent cohorts report greater age-specific limitations than their predecessors. A trend function coefficient of 0 indicates perfect convergence: aging trajectories are identical for all cohorts.

Each trend function is further decomposed into two linear terms: one age-independent and one age-dependent. The age-independent term quantifies intercohort gaps that are constant over age. The age-dependent term is the age-varying component of intercohort gaps. Both terms can take negative and positive values. Significant positive age-independent and dependent terms imply upward intercohort gaps (i.e., worsening functional risk) that widen with respect to age.

Based on the full model (presented in Table 3), Table 4 summarizes the trend function for each country. In the United States, the age-independent constant term was 0.079, and the age-dependent linear term was 0.003: these terms were statistically significant. Thus, compared with the reference cohort (born in 1940), those who were born in 1941 had

0.079 more functional limitations at any given age. At later ages, that initial health disadvantage of the younger cohort widened: they accrued 0.003 more functional limitations each year than the reference cohort. Although these numbers may seem small, the consequences of these intercohort trends are substantial for younger cohorts. For example, at the age of 64, members of the 1950 birth cohort will have accumulated 0.8 additional functional limitations than their peers born in 1940 ($0.079 \times 10 = 0.79$), and they will accumulate functional limitations at a faster rate each subsequent year. Comparisons of the trend functions across the countries in Table 4 reveal that the age-independent term was significant in the same direction (positive) for all countries, meaning that more recent cohorts had more functional limitations at any given age. For three countries other than the United States, the positive age-dependent term was also statistically significant: Austria, England, and Spain.

We further illustrate these intercohort trends in Fig. 2 through the construction of virtual cohort curves for the 1930, 1940, and 1950 cohorts for each country. Calculation of virtual cohort curves relies on the trend function. The trend function was used as an additive modifier to the cross-sectional curve equation (Mirowsky 2013). The average intercept for the United States is 1.541, and the average slope is 0.084. The curve for the reference cohort group (born in 1940) is based on the following equation: $1.541 + (-0.005 + 0.079) \times age + (0.001 + 0.003) \times age^2$. The curve for those who were born 10 years prior (1930) is expressed as follows: $(1.541 - 0.079 \times 10) + (0.001 + 0.003 - 0.003 \times 10) \times age + (0.001 + 0.003) \times age^2$. Observe that we first used the trend function to establish the virtual cohort curve for the reference cohort and then to project curves for other cohorts based on differences in birth year.

Comparing the virtual cohort curves for 1930, 1940, and 1950 cohorts, we again observed that younger cohorts tended to report more limitations than their older peers. As seen for the United States, England, Austria, Spain, Belgium, and to a lesser extent, Italy, gaps in virtual cohort curves widened across the 1930, 1940, and 1950 cohorts. For example, the top-right of Fig. 2 displays intercohort trends in Austria, showing widening intercohort gaps with age. Similar to the United States in magnitude, 1950 cohort members in Austria had roughly as many functional limitations in their 70s as 1930 cohort members did in their 80s. In sum, we observed worsening intercohort trends of functional limitations across the countries, significantly differentiating aging trajectories among future cohorts. The overall magnitude of these upward intercohort trends was greater for the United States, the UK, Austria, Spain, and Belgium than for the remaining countries, mainly because of the widening of those gaps with regard to age. In other words, the acceleration of aging in terms of functional limitations was uniquely observed in those five countries.

Discussion

The present study brought together the comparative and life course perspectives to examine international differences in functional health trajectories and the roles of cohort dynamics and life course factors in their genesis. We focused on functional limitation because this represents a measure of overall health that reflects both the presence and consequences of chronic health conditions (Pinsky et al. 1990), reflects progression through the disablement process, and is strongly associated with mortality (Majer et al. 2011).

Combining this comparative cohort-based trajectory approach with the aging vector analytic model yielded insights into diverging health trends, driven in part by

Table 4 Trend function estimates (standard errors) based on the full conditional model

						Trend Function Parameters[c]					
							95 % CI			95 % CI	
	Mean Intercept[a]	Mean Slope[a]	Age on Intercept[b]	Age Squared on Intercept[b]	Age on Slope[b]	Age-Independent	Lower	Higher	Age-Dependent	Lower	Higher
United States	1.541 (0.016)	0.084 (0.002)	0.005 (0.001)	0.001 (0.000)	0.005 (0.000)	**0.079** (0.002)	0.075	0.083	**0.003** (0.001)	0.002	0.004
England	1.196 (0.029)	0.053 (0.003)	0.014 (0.003)	0.001 (0.000)	0.005 (0.000)	**0.039** (0.004)	0.031	0.047	**0.003** (0.001)	0.002	0.004
Austria	0.732 (0.047)	0.079 (0.007)	0.006 (0.006)	0.003 (0.000)	0.010 (0.001)	**0.073** (0.010)	0.054	0.092	**0.004** (0.001)	0.002	0.006
Germany	0.747 (0.039)	0.062 (0.005)	0.030 (0.005)	0.002 (0.000)	0.004 (0.001)	**0.032** (0.008)	0.017	0.047	0.000 (0.001)	–0.002	0.002
Sweden	0.450 (0.029)	0.038 (0.004)	0.005 (0.003)	0.002 (0.000)	0.005 (0.001)	**0.033** (0.005)	0.022	0.044	0.001 (0.001)	–0.001	0.003
Netherlands	0.571 (0.034)	0.042 (0.004)	0.003 (0.003)	0.002 (0.000)	0.004 (0.001)	**0.039** (0.005)	0.028	0.050	0.000 (0.001)	–0.002	0.002
Spain	1.133 (0.045)	0.067 (0.005)	0.031 (0.005)	0.002 (0.000)	0.008 (0.001)	**0.036** (0.008)	0.021	0.051	**0.004** (0.001)	0.002	0.006
Italy	1.561 (0.114)	0.086 (0.005)	0.050 (0.004)	0.002 (0.000)	0.006 (0.001)	**0.036** (0.007)	0.022	0.050	0.002 (0.001)	0.000	0.004
France	1.467 (0.104)	0.075 (0.004)	0.022 (0.003)	0.003 (0.000)	0.006 (0.001)	**0.053** (0.006)	0.042	0.064	0.000 (0.001)	–0.002	0.002
Denmark	0.481 (0.036)	0.049 (0.005)	0.006 (0.004)	0.002 (0.000)	0.004 (0.001)	**0.043** (0.007)	0.029	0.057	0.000 (0.001)	–0.002	0.002
Switzerland	0.367 (0.037)	0.033 (0.005)	0.002 (0.004)	0.002 (0.000)	0.005 (0.001)	**0.031** (0.007)	0.017	0.045	0.001 (0.001)	–0.001	0.003
Belgium	1.474 (0.094)	0.079 (0.004)	0.017 (0.003)	0.002 (0.000)	0.006 (0.001)	**0.062** (0.005)	0.051	0.073	0.002 (0.001)	0.000	0.004

[a] The intercept and slope are population averages calculated by multiplying the coefficient of each covariate from Table 3 by its population mean/proportion. For instance, for Female, we multiplied its coefficient (0.477) and sample proportion from Table 1 (0.501), and then we added the product terms for all covariates to the constant. Standard errors were calculated using the delta method.

[b] Parameters were drawn from Table 3.

[c] The trend function has two terms: age-independent and age-dependent. The age-independent term was calculated as Average slope – Age coefficient predicting intercept, and the age-dependent term was calculated as the Age coefficient predicting slope – 2 × Age Squared coefficient predicting the intercept (Kim 2008; Mirowsky 2013). Values in bold are statistically significant.

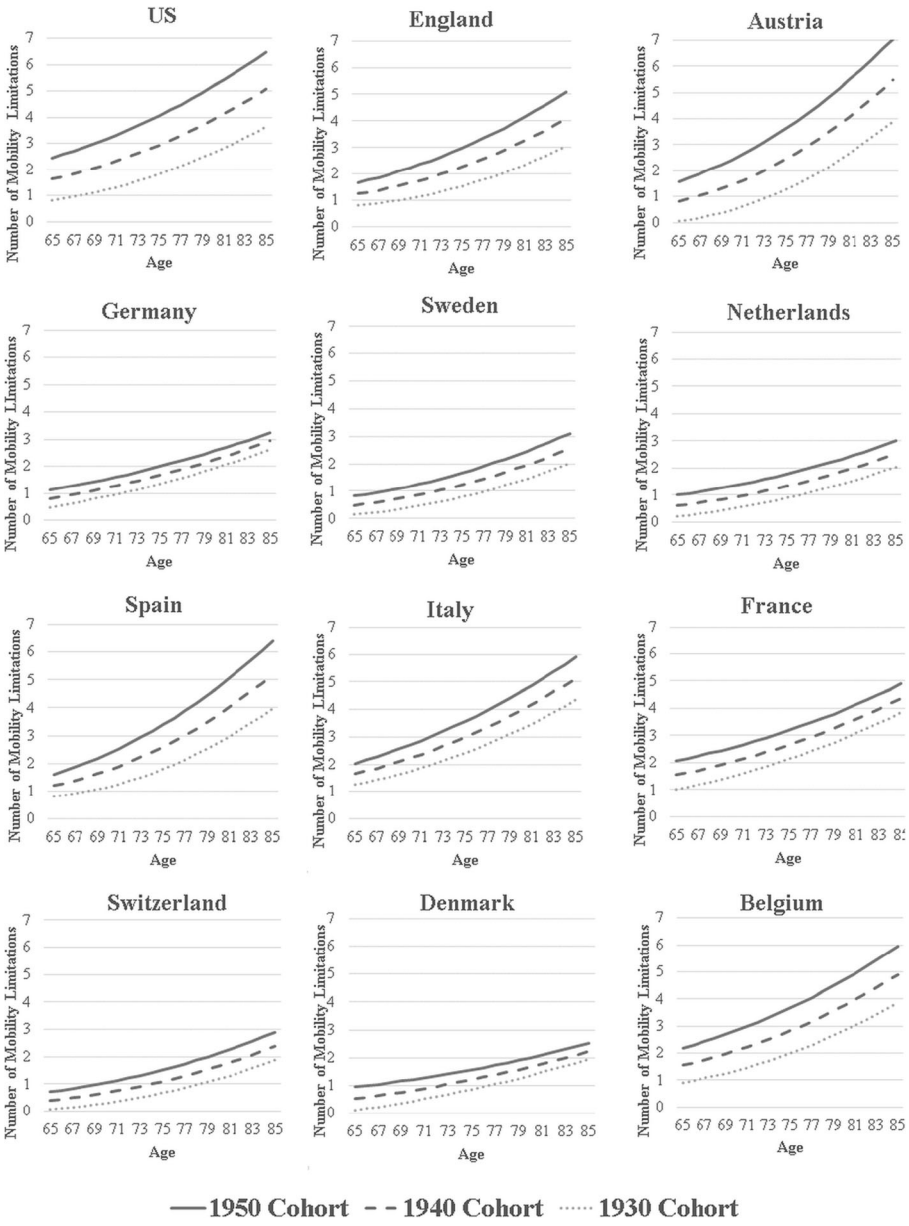

Fig. 2 Virtual cohort projections, by country: 1930, 1940, and 1950 cohorts

heterogeneous intercohort trends, which would be elusive otherwise. We observed significant intercohort trends across all countries, even after controlling for differential exposure to known risk factors. This evidence confirms that aging trajectories are deeply embedded in time and place, casting a new light on between-country comparisons of health.

The trend function quantifies cohort differences in aging trajectories across countries. In the countries studied here, younger cohorts are experiencing higher risks at baseline compared with their older counterparts. For most countries, this initial gap appears stable

with age; for the United States, England, Austria, and Spain, the gap widens as younger cohorts progress through their older years. It is unclear whether such trends are likely to improve. Trends in the United States are particularly concerning. Combining these higher risks with high rates of obesity among more recent cohorts, the United States is likely to see the continued growth in the prevalence of functional limitation and attendant disability. The observed cohort patterns also fit with recent trends in mortality in the United States. Rising mortality among middle-aged non-Hispanic whites, especially among those with low SES, portend rising levels of social and economic distress (Case and Deaton 2015; Montez and Zajacova 2013). That similar patterns were found further upstream suggests that these represent secular trends rather than short-term period effects. Although obesity rates in Europe are lower than in the United States, prevalence continues to rise (Sassi et al. 2009), which is likely to have adverse impacts on these cohorts as they age, magnifying the patterns we observed. Although Europe has not seen the same troubling mortality trends observed in the United States, the cohort patterns observed here suggest the possibility of a slowing down of the mortality decline in some countries. The mixed intercohort patterns that we observed across European countries also fit with the emerging evidence of heterogeneous disability trends in the region (Verropolou and Tsimbos 2016). Future research would be wise to investigate international variation in cohort processes and to take that variation into account in cross-national comparisons. Our analysis was not designed to test the compression of morbidity hypothesis. However, our observation of expanding functional limitation among more recent cohorts is inconsistent with compression.

The findings also shed additional light on the processes underlying the early origins of disease. We found that countries differentially exposed their members to a wide variety of life course factors that influence health trajectories, including poor health early in life, which had lasting negative impacts on functional health trajectories, with very little attenuation by adult socioeconomic conditions and behavioral lifestyle factors. We further found that the magnitude of these effects varies across context (see Table 5 in the appendix), which is strongly consistent with a critical/sensitive period effect. Conversely, the impact of childhood socioeconomic conditions is largely mediated by subsequent socioeconomic attainment. This is more consistent with an accumulation or, in some cases, a chains-of-risk process. Together, these findings suggest that different types of early-life exposures exert their influence through very different causal and etiologic processes. Some exposures appear to operate primarily through critical/sensitive period processes, while others work through generalized processes of risk accumulation, confirming that these approaches need not be considered mutually exclusive (Blane et al. 2007).

Although life course factors were important determinants of functional health trajectories in all contexts (to varying degrees), we also found that cohort and international differences in trajectories persisted net of them. Differences in institutional context that go uncaptured in individual-level data may further explain some of the international variation in functional health trajectories and their disparate cohort patterns. The U.S. welfare state has long been less universal in coverage, less generous in provision, and more piecemeal in scope than its European peers. It has thus tolerated a lower floor of support and larger socioeconomic and racial inequalities (Hummer et al. 1999; Kunitz and Pesis-Katz 2005). However, the countries with disparate cohort trends do not form a clear cluster along institutional lines, with the United States, Spain, England, and Austria having very different welfare state regimes. Further complicating attempts to understand the potential influence of institutional factors on differences in aging trajectories is that like health, welfare state and other

institutional arrangements themselves are dynamic over the long sweep of time covered by the cohorts under study. Similarly, although the analysis can point to one or two life course factors that may help explain patterns in each of these countries—aside from Spain, England, and Austria all having comparatively low household incomes—no clear patterns emerged among the observable characteristics to explain why these countries in particular are experiencing cohort divergence. More research is needed to document and explain the causes of these cohort dynamics. Given the central role of chronic disease in the broader disablement process, examining divergent intercohort trends in the upstream determinants of functional health trajectories, including shifts in chronic disease incidence and prevalence and their psychosocial antecedents (i.e., obesity, smoking), may hold important answers. Indeed, recent work has highlighted divergence in age-related patterns of a variety of chronic diseases between the United States and Europe as a whole (Solé-Auró et al. 2015). However, disease trends across the continent are clearly heterogeneous, and understanding that heterogeneity will likely hold the key to unpacking cohort divergence in functional health.

Although their macro-level causes remain unclear, the policy implications of these trends are not. All aging societies must grapple with shifts in the labor force, rising dependency ratios, and the associated costs of supporting an increasingly aged population. However, the cohort trends observed in this article are likely to exacerbate these issues in some contexts. As the number of disabled adults rises, so too does the number of workers prematurely exiting the labor force (Martin et al. 2010). This shift results in further lost productivity, rising health care costs, and increased reliance on private and public disability insurance. In the United States, for example, illness results in lost economic productivity equaling $260 billion annually (Davis et al. 2005). Additionally, Social Security Disability Insurance payments to disabled adults cost more than $120 billion annually (Social Security Administration 2016). Additional growth in the disabled population will place further stress on already strained resources. However, the policy implications of the results are not all bad. The universal and persistent impact of childhood health on functional health trajectories over the life course also suggests that policy-makers can leverage investments in early-life health to improve a wide variety of health and policy goals long into the future. Evidence suggests that such early-life investments in disadvantaged populations are more productive and cost-efficient than those made in adulthood (Heckman and Masterov 2007).

There are several caveats to our findings, many of which are inherent in the dearth of comparable population data across countries. The absence of data linking early-life health and socioeconomic characteristics with later-life health trajectories across a wider array of international contexts is an important limitation. Our analysis is limited to affluent industrialized countries in Europe and the United States, where the epidemiological transition occurred in similar historic periods and was driven by a common constellation of technological and sociohistorical transformations (Fogel and Costa 1997). Thus, the country contexts examined here make up a small fraction of variation at the global level. Developing country contexts may show very different patterns in intercohort trends over time. Hopefully, in the future, more aging studies will collect childhood health histories, allowing a more extensive analysis across a wider array of contexts.

Second, although the various surveys that we used were all modeled after the HRS and were designed to be comparable, concerns remain about inconsistent measurement across countries. Considerable effort has been made to validate measures of adult health such as functional limitations and chronic conditions, but analysis of the comparative validity of retrospective childhood measures across international contexts is limited. We

are aware of only one prior study that documented the validity of retrospective childhood health histories cross-culturally (Havari and Mazzonna 2015).

Despite these limitations, we believe that the approach used here provides unique opportunities to investigate the determinants of population health. The findings highlight the importance of varied intercohort processes in driving international differences in functional health. Future research on population health would benefit from an examination of cohort dynamics and combine these with an examination of a wider array of institutional, policy, and historical forces linked to time and place that leave behind heterogeneous imprints on health.

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Appendix

Table 5 Model comparison testing variation in coefficients across the samples

Model	Number of Parameters	Log-Likelihood	χ^{2a}	AIC	BIC
1. Full Model from Table 3	775	–998,781		1,999,113	2,003,713
2. Equal Effects of Gender on Intercept and Slope	751	–1,000,080	2,768***	2,001,663	2,006,120
3. Equal Effect of Poor Childhood Health on Intercept and Slope	751	–999,899	1,553***	2,001,300	2,005,757
4. Equal Effect of Father's Occupation on Intercept and Slope	751	–1,000,723	4,776***	2,002,949	2,007,406
5. Equal Effect of Low Parental Education on Intercept and Slope	751	–1,000,507	3,940***	2,002,515	2,006,972
6. Equal Effect of Marital Status on Intercept and Slope	751	–1,001,357	5,679***	2,004,217	2,008,674
7. Equal Effect of Education on Intercept and Slope	751	–1,002,881	29,155***	2,007,264	2,011,721
8. Equal Effect of Medium and High Occupation on Intercept and Slope	727	–1,004,167	14,069***	2,009,788	2,014,102
9. Equal Effect of Income on Intercept and Slope	751	–1,002,721	14,823***	2,006,945	2,011,402
10. Equal Effect of any Chronic Condition on Intercept and Slope	751	–999,914	2,336***	2,001,330	2,005,787
11. Equal Effect of BMI on Intercept and Slope	751	–1,002,982	19,195***	2,007,466	2,011,923
12. Equal Effect of Current and Former Smoking on Intercept and Slope	727	–1,003,540	10,552***	2,008,535	2,012,850

[a] Satorra-Bentler scaled chi-square difference test.

***$p < .001$

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