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Assessing morbidity compression in two cohorts from the Health and Retirement Study

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ABSTRACT

Background Increases in life expectancy are hypothesised to be associated with shorter proportional time spent with morbidity (compression of morbidity). We assessed whether this has occurred among older adults in the USA during the 1990s and 2000s.

Methods We used data from the Health and Retirement Study to estimate a morbidity score based on eight chronic conditions and compare it (1) prospectively between two age-matched cohorts in 1992 and 2004 over a 6-year follow-up, and (2) retrospectively in the three waves prior to death among respondents who die in (1998–2004) and (2004–2010).

Results Prospective assessment shows significantly higher prevalence in 6 of eight chronic conditions in the 2000s, with 37% higher diabetes prevalence. A retrospective evaluation shows significantly higher prevalence in 7 of eight chronic conditions in the three waves prior to death for (2004–2010) versus (1998–2004), with 41% higher prevalence of arthritis. Importantly, the farther away from time of death, the higher the average number of chronic conditions in (2004–2010).

Conclusions Using the largest longitudinal ageing study in the USA, we found no clear evidence of compression of morbidity as measured by self-reported chronic disease. Older adults in the USA may be experiencing greater disease burden in recent times.

INTRODUCTION

Continuous increase in life expectancy raises concerns about the quality of the added years of life at older ages. A central framework for studying healthy ageing is that of compression of morbidity posited by Fries in 1980,[1] which states that onset of chronic conditions should be delayed at a faster rate than increases in survival leading to shorter proportional time spend with morbidity (compression). Additional work suggests that compression of morbidity is linked with healthy behaviours whereby individuals who engage in healthy habits are more likely to compress their morbidity (measured by disability) into fewer years of life.[2 3] In this paper, we test the conjecture of compression of morbidity using the largest longitudinal ageing study in the USA—the Health and Retirement Study (HRS)—to assess changes in morbidity as measured by self-reported chronic disease in the 1990s and 2000s.

Compression of morbidity is empirically assessed in the literature either prospectively or retrospectively. A prospective approach links survival changes with morbidity status by following a cohort of individuals over time and length of life with and without morbidity is gauged from incident transition probabilities.[4–6] In the absence of longitudinal data, length of life with and without morbidity is estimated at two time points using cross-sectional data by proportionally allocating years of life from a life table in each morbidity state and the changes in survival are assessed.[7–10] Contrary to this approach, a retrospective assessment estimates length of life with and without morbidity before death.[11] Under this approach, it is important to identify whether morbidity occurs in periods of time far away from the end of life, in which case there would be more years in poor health (ie, expansion of morbidity). It thus follows that under this approach, compression of morbidity would predict that morbidity occurs in periods closer to death (ie, sharp rises in disability near death); thus, morbidity status is compared at similar times before death among cohorts.

Under compression of morbidity the previous approaches lead to the following testable hypotheses. If survival increases over time, compression of morbidity would predict individuals in recent times to have lower morbidity than those in the past when prospectively assessed, or that morbidity improves in the time period before death in recent times when retrospectively assessed—that is, morbidity would be pushed to periods just before death in recent times leading to a compression of morbidity (or relative morbidity).[3 11]

Empirical evidence on compression of morbidity since the 1980s has focused on patterns and trends in the indicators of disability (eg, independent ability to take a bath or go to the toilet) and functional limitations (eg, standing or bending) with mixed results.[4 5 8 12] This approach is primarily rooted on understanding the disablement process, which is thought to be influenced by the interaction of physical ability (intraindividual) and environmental challenge (extraindividual).[13] Recent evidence, for example, shows a worsening in disability rates among people aged 50–64 years and stagnation among those older than 85 years,[14] although reductions in disability prevalence among older people (aged 65+ years) appeared to exist in the USA until the 90s.[15] More worrisome are the increases in disability rates that have been observed among younger American adults (aged 40–64 years) in recent years.[16] Additional evidence indicates higher morbidity among older adults in recent times (eg, expansion of morbidity) when using chronic disease prevalence as the measure of morbidity.[12] Other research, however, indicates compression of morbidity when using disability-related or impairment-related measures regardless of how compression of morbidity is evaluated (ie, prospectively or retrospectively).[12] For example, some

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research using disability indicators suggest that disability is increasingly compressed within the past 2 years before death.[11 17]

In this paper, we use data from the HRS to assess changes in morbidity using both prospective and retrospective approaches (figure 1). We prospectively compare the morbidity status between two age-matched cohorts aged 51–61 years during the 1990s (1992–1998) and 2000s (2004–2010; figure 1A), and retrospectively assess average morbidity status in the three waves prior to death for respondents who die between 1998–2004 and 2004–2010 (figure 1B).

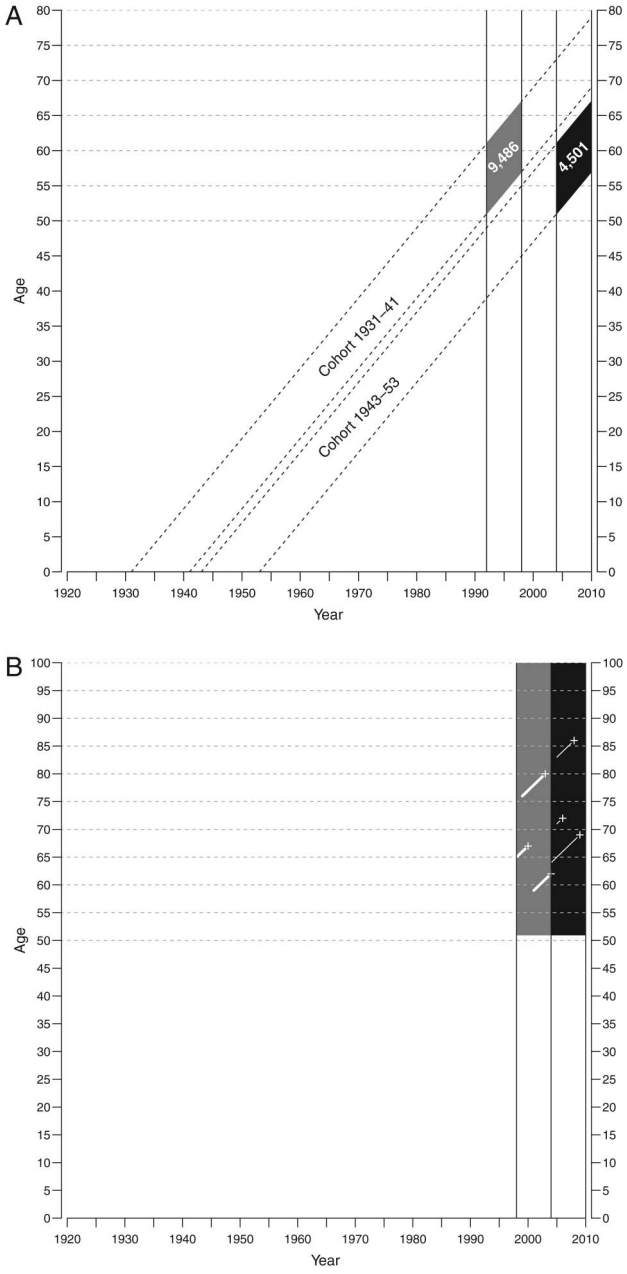

Figure 1 Prospective (A) and Retrospective (B) Assessment of Compression of Morbidity in the Health and Retirement Study (HRS). (A) Prevalence of health conditions are estimated during each 6-year follow-up; numbers in each figure correspond to sample sizes. In (B) diagonal lines represent deceased respondents between 1998–2004 (thick white line) and 2004–2010 (thin white line); the length of each line corresponds to the time that elapsed before death.

METHODS

We use data from the HRS in the USA which is a large and heterogeneous sample of adults aged 50 years or older, with long longitudinal follow-up.[18] The baseline interview was conducted in 1992 with follow-up interviews every 2 years up to 2010. Proxy respondents are allowed to provide responses for individuals who are unavailable or unable to participate in the interview. We used two approaches to assess the morbidity status for each cohort, prospectively and retrospectively. First, we followed each cohort in 1992 (n=9486) and 2004 (n=4501) for 6 years and recorded the number of self-reported chronic conditions that occurred at any time during the follow-up (figure 1A). Second, we identify respondents who die within two periods (1998–2004 and 2004–2010) and recorded the number of chronic conditions for the last three waves prior to death. We used date of death to identify two groups with similar follow-up time 1998–2004 and 2004–2010. We only considered people who died after the age of 50 years. The retrospective approach for the first cohort starts in 1998 because the original HRS cohort in 1992 only included people aged 51–61 years; in 1998, a new cohort was added that includes all ages of 50+ years. We assumed that when respondents self-report having a chronic disease in a given wave, they remain in that state thereafter. Mortality is assessed at any time during the follow-up for each period. This approach allowed us to assess morbidity compression prospectively among all age-matched cohort members as well as retrospectively among those who die within a similar observation period in the late 1990s and late 2000's. We included 7 chronic disease conditions assessed by self-reports (cancer, diabetes, high-blood pressure, lung disease, heart disease, stroke and arthritis) and 1 indicator of psychiatric disorders assessed by the question "Has a doctor ever told you that you had emotional, nervous, or psychiatric problems?"

Table 1 Health conditions in 1992 and in 2004 for respondents aged 51–6 1years in the Health and Retirement study for the prospective sample

	1992		2004		
Covariates	**Per cent**	**N**	**Per cent**	**N**	**p Value**
Cancer	9.65	915	11.02	496	0.01
Diabetes	16.56	1571	22.71	1022	<0.0001
High-blood pressure	50.03	4746	55.23	2486	<0.0001
Lung disease	12.34	1171	9.69	436	<0.0001
Heart disease	19.97	1894	19.06	858	0.21
Stroke	4.97	471	5.04	227	0.84
Arthritis	55.27	5243	52.32	2355	0.001
Psychiatric disorder	18.23	1729	23.17	1043	<0.0001
Morbidity score*					
Men					
Mean	−9.49E-17	4367	6.11E-17	2157	<0.010
Standardised	−3.81E-16	4367	7.18E-17	2157	<0.010
Women					
Mean	−6.66E-16	5119	1.60E-16	2344	<0.0001
Standardised	5.18E-16	5119	3.85E-16	2344	<0.0001
Total					
Mean	−4.28E-16	9486	−7.20E-16	4501	<0.0001
Standardised	−7.72E-16	9486	−7.57E-16	4501	<0.0001

Unweighted values. p Values are estimated based on two-tailed tests of differences in proportions or differences in means, depending on the outcome.
*Morbidity score estimated from factor analysis is carried out separately by sex and time period based on the self-reported conditions.

Table 2 Health conditions for respondents who died* in 1998–2004 and in 2004–2010 in the Health and Retirement Study for the retrospective sample

	1 wave prior to death					2 waves prior to death					3 waves prior to death				
	1998–2004		2004–2010			1998–2004		2004–2010			1998–2004		2004–2010		
Covariates	Per cent	N	Per cent	N	p Value	Per cent	N	Per cent	N	p Value	Per cent	N	Per cent	N	p Value
Health conditions															
Cancer	24.22	1234	26.81	1216	0.0036	17.23	842	20.73	920	<0.0001	13.25	469	17.47	739	<0.0001
Diabetes	25.53	1299	30.40	1378	<0.0001	22.46	1097	27.65	1227	<0.0001	19.1	667	25.04	1059	<0.0001
High BP	61.42	3123	71.54	3238	<0.0001	57.03	2783	67.04	2970	<0.0001	51.02	1729	62.2	2630	<0.0001
Lung dis	21.27	1083	21.83	990	0.5103	17.4	851	17.89	794	0.533	13.34	470	14.88	629	0.054
Heart dis	47.23	2407	50.35	2283	0.0022	40.81	1995	44.35	1966	0.0006	33.16	1185	38.02	1607	<0.0001
Stroke	19.76	1005	19.93	903	0.831	14.86	726	16.14	716	0.086	10.91	386	12.91	546	0.007
Arthritis	63.53	3230	73.46	3330	<0.0001	53.45	2609	70.49	3124	<0.0001	46.92	1615	66.4	2804	<0.0001
Psychiatric disorder	21.66	929	27.42	1117	<0.0001	16.76	687	22.93	913	<0.0001	12.95	357	17.55	666	<0.0001
Morbidity score															
Men															
Mean	−8.3E-17	2046	−3.2E-17	1842	0.272	−1.2E-16	1929	8.3E-17	1797	0.618	−2.4E-16	1182	−9.0E-17	1709	0.501
Standardised	4.6E-17	2046	8.2E-18	1842	0.272	7.7E-17	1929	6.9E-17	1797	0.618	−9.4E-17	1182	3.9E-17	1709	0.501
Women															
Mean	−1.7E-16	2212	1.9E-17	2194	0.112	5.7E-17	2140	5.4E-17	2153	0.5127	−6.4E-17	1347	−1.3E-16	2070	0.524
Standardised	9.2E-17	2212	5.2E-17	2194	0.112	1.9E-17	2140	6.9E-17	2153	0.5127	−1.0E-16	1347	−1.7E-16	2070	0.524

p Values are estimated based on two-tailed tests of differences in proportions or differences in means, depending on the outcome.
*Deceased individuals for whom we have information in the first, second and third waves prior to death; death occurred at any point during the 6-year follow-up. Descriptive characteristics correspond to those in the wave prior to death.
BP, blood pressure; dis, disease.

The Harvard University institutional review board approved the study.

Statistical analysis

We used two approaches to assess the association between a morbidity indicator and time period controlling of the socioeconomic indicators. First, we used factor analysis to estimate an underlying morbidity indicator separately by sex and time period based on self-reported conditions. We retain the first component and estimated an underlying morbidity score for each respondent (online supplementary appendix figure 1 shows factor loadings by sex, time period and chronic condition). Second, we estimated a series of linear regression models to assess the association between the predicted morbidity score with time period controlling for age, race and other socioeconomic indicators (eg, education). We estimated similar

Table 3 Association of a morbidity score and the number of chronic conditions with time period and socioeconomic status by sex for the prospective age-matched samples: HRS 1992–1998 and 2004–2010

	Morbidity score				Number of chronic conditions			
	Men		Women		Men		Women	
Covariates	Coeff	95% CI	Coeff	95% CI	Coeff	95% CI	Coeff	95% CI
Period (ref=1992–1998)								
2004–2010	0.13	(0.07 to 0.19)	0.14	(0.09 to 0.20)	0.16	(0.09 to 0.24)	0.29	(0.21 to 0.36)
Age	0.02	(0.01 to 0.03)	0.02	(0.01 to 0.03)	0.05	(0.04 to 0.06)	0.05	(0.04 to 0.06)
Race (ref=white)								
Black	0.25	(0.18 to 0.33)	0.46	(0.40 to 0.53)	0.11	(0.02 to 0.21)	0.45	(0.37 to 0.54)
Other	0.06		0.18	(0.06 to 0.29)	−0.15	(−0.3 to −0.01)	0.11	(−0.03 to 0.26)
Education (ref=<high school)								
GED-high school	−0.11	(−0.19 to −0.04)	−0.22	(−0.29 to −0.15)	−0.13	(−0.22 to −0.03)	−0.43	(−0.52 to −0.34)
College/college+	−0.16	(−0.23 to −0.09)	−0.33	(−0.41 to −0.26)	−0.28	(−0.37 to −0.18)	−0.59	(−0.69 to −0.50)
Income quartiles (ref=Q1)								
2nd quartile (Q2)	−0.36	(−0.44 to −0.27)	−0.19	(−0.26 to −0.13)	−0.51	(−0.62 to −0.40)	−0.36	(−0.45 to −0.28)
3rd quartile (Q3)	−0.44	(−0.52 to −0.37)	−0.25	(−0.32 to −0.19)	−0.70	(−0.80 to −0.60)	−0.49	(−0.58 to −0.41)
4th quartile (Q4)	−0.45	(−0.52 to −0.38)	−0.32	(−0.40 to −0.23)	−0.77	(−0.87 to −0.68)	−0.61	(−0.72 to −0.49)
Sample size	6524		7462		6524		7462	

Results from a multivariate linear regression predicting the average morbidity score, and the average number of chronic conditions.
Coeff, coefficient; HRS, Health and Retirement Study.

models for both, the prospective and retrospective samples. All models were estimated separately for men and women.

RESULTS

Prevalence of chronic disease conditions are shown in tables 1 and 2 for the prospective and retrospective samples, respectively. Basic sociodemographic characteristics of each cohort are shown in online supplementary material. Results for the prospective sample (table 1) indicate higher prevalence of cancer, diabetes, high-blood pressure and psychiatric disorders in recent times (in the 2000's) with no significant difference in cardiovascular disease (eg, heart disease and stroke), but lower prevalence of lung disease and arthritis. Importantly, the cohort in the 2000's has about 37% higher prevalence of diabetes, a condition that associates with high disease burden due to fear of complications and associated hopelessness, depression, and work discrimination.[19] Additionally, arthritis, high-blood pressure, and cardiovascular diseases were the most prevalent conditions in both periods. Summarising these conditions by a morbidity score also suggests a higher prevalence of chronic disease in men and women in the 2000's.

Moreover, results for the retrospective sample (deceased sample) overwhelmingly indicate that older adults who die during 2004–2010 had significantly higher prevalence in most chronic conditions in any of the three waves prior to death than their counterparts who died in 1998–2004 (table 2). At times further from death (wave 3 prior to death), for example, those who died in 2004–2010 had significantly higher prevalence in all chronic conditions except lung disease. Importantly, those who die in 2004–2010 have about 31% higher prevalence of cancer and diabetes, and about 41% higher prevalence of arthritis —a chronic condition associated with high disease burden and disability—3 waves prior to death. Summarising these conditions by a morbidity score does not indicate significant differences in the score in waves prior to death. Since we are studying chronic conditions, once an individual self-reports one of these diseases, he/she remains in that condition in the waves that follow. This implies that the

Table 4 Association of a morbidity score and the number of chronic conditions with time period and socioeconomic status by sex for the retrospective samples: HRS 1998–2004 and 2004–2010

	Morbidity score				Number of chronic conditions			
	Men		Women		Men		Women	
Covariates	Coeff	95% CI	Coeff	95% CI	Coeff	95% CI	Coeff	95% CI
1 wave prior to death								
Period (ref=1998–2004)								
2004–2010	0.024	(−0.043 to 0.090)	0.007	(−0.054 to 0.069)	0.325	(0.232 to 0.419)	0.459	(0.374 to 0.544)
Age	−0.005	(−0.008 to −0.001)	−0.001	(−0.004 to 0.002)	−0.003	(−0.007 to 0.002)	−0.011	(−0.015 to −0.007)
Race (ref=white)								
Black	0.234	(0.139 to 0.330)	0.053	(−0.031 to 0.136)	−0.032	(−0.166 to 0.103)	0.042	(−0.074 to 0.158)
Other	0.030	(−0.160 to 0.220)	0.080	(−0.110 to 0.269)	−0.264	(−0.529 to 0.001)	−0.041	(−0.304 to 0.222)
Education (ref=<high school)								
GED-high school	−0.069	(−0.151 to 0.012)	−0.189	(−0.261 to −0.117)	−0.122	(−0.236 to −0.007)	−0.332	(−0.432 to −0.232)
College/college+	−0.123	(−0.205 to −0.041)	−0.296	(−0.376 to −0.217)	−0.292	(−0.408 to −0.176)	−0.442	(−0.551 to −0.332)
Sample size	3568		4090		4155		4741	
2 waves prior to death								
Period (ref=1998–2004)								
2004–2010	0.014	(−0.054 to 0.081)	0.037	(−0.024 to 0.098)	0.395	(0.302 to 0.487)	0.595	(0.510 to 0.679)
Age	−0.005	(−0.008 to −0.001)	−0.001	(−0.003 to 0.002)	−0.003	(−0.007 to 0.002)	−0.013	(−0.017 to −0.009)
Race (ref=white)								
Black	0.274	(0.177 to 0.371)	0.364	(0.280 to 0.447)	−0.001	(−0.134 to 0.132)	0.043	(−0.072 to 0.158)
Other	−0.012	(−0.207 to 0.183)	0.206	(0.012 to 0.399)	−0.244	(−0.507 to 0.019)	−0.015	(−0.281 to 0.251)
Education (ref=<high school)								
GED-high school	−0.006	(−0.089 to 0.077)	−0.216	(−0.288 to −0.144)	−0.043	(−0.156 to 0.070)	−0.332	(−0.431 to −0.233)
College/college+	−0.081	(−0.164 to 0.003)	−0.329	(−0.408 to −0.250)	−0.259	(−0.373 to −0.145)	−0.393	(−0.502 to −0.284)
Sample size	3407		3977		3978		4613	
3 waves prior to death								
Period (ref=1998–2004)								
2004–2010	0.010	(−0.068 to 0.087)	0.049	(−0.021 to 0.120)	0.560	(0.464 to 0.656)	0.665	(0.575 to 0.756)
Age	−0.004	(−0.008 to −0.0001)	−0.005	(−0.008 to −0.002)	0.007	(0.002 to 0.012)	−0.004	(−0.008 to −0.000)
Race (ref=white)								
Black	0.235	(0.124 to 0.346)	0.355	(0.260 to 0.450)	0.026	(−0.114 to 0.166)	0.112	(−0.010 to 0.235)
Other	−0.005	(−0.227 to 0.218)	0.060	(−0.164 to 0.284)	−0.215	(−0.493 to 0.064)	−0.089	(−0.377 to 0.198)
Education (ref=<high school)								
GED-high school	−0.054	(−0.147 to 0.040)	−0.252	(−0.333 to −0.171)	−0.069	(−0.186 to 0.048)	−0.309	(−0.415 to −0.203)
College/college+	−0.096	(−0.191 to −0.002)	−0.312	(−0.401 to −0.223)	−0.188	(−0.307 to −0.070)	−0.335	(−0.451 to −0.220)
Sample size	2655		3177		3342		3872	

Results from a multivariate linear regression predicting the average morbidity score, and the average number of chronic conditions.
HRS, Health and Retirement Study.

farther away from death, the fewer the disease cases and the lower the prevalence.

Associations between morbidity status, time period and socioeconomic status (SES) for the prospective sample are shown in table 3. Results show significantly higher morbidity score for both men and women in the recent time period 2004–2010 relative to their counterparts in the 1990s (1992–1998), a result that holds for both the morbidity score and the number of chronic conditions. In addition, these results highlight significant racial and SES differences where blacks and those with low SES had higher average morbidity score and higher average number of chronic conditions in recent times relative to their counterparts in the 1990s.

Results comparing the morbidity status between the two cohorts for the retrospective sample (deceased sample) controlling for age before death, SES and race are shown in table 4. Results indicate no significant differences in the morbidity score between those who die in 1998–2004 and 2004–2010 in any of the three waves prior to death. However, those who die in 2004–2010 have significantly higher number of chronic conditions prior to death in any of the three waves prior to death. Importantly, the farther away from time of death, the higher the average number of self-reported chronic conditions for those who die in recent times. These results hold for both men and women. The negative effect of age, although small, may suggest a health selection effect. However, this effect is not consistent in all models.

DISCUSSION

A central framework for studying healthy ageing is that of compression of morbidity posited by Fries in 1980[1] in which he stated that the onset of chronic conditions should be delayed at a faster rate than increases in survival, thus leading to a shorter proportional time spend with morbidity (compression). This analysis shows that when morbidity is measured by self-reported chronic conditions, there is no clear evidence of a lower morbidity toll among recent cohorts. Results show higher prevalence of chronic conditions in recent times among adults aged 51–61 years when comparing age-matched cohorts between 1992–1998 and 2004–2010. This is particularly true for cancer, diabetes, high-blood pressure and psychiatric disorders. Moreover, older adults who died during 2004–2010 had significantly higher prevalence of most chronic conditions prior to death than their counterparts who died in 1998–2004, except for lung disease and stroke. Importantly, those who die in 2004–2010 have about 31% higher prevalence of cancer and diabetes, and about 41% higher prevalence of arthritis —a chronic condition associated with high disease burden and disability—3 waves prior to death.

Evidence on compression of morbidity since the 1980s has focused on patterns and trends in indicators of disability (eg, independent ability to take a bath or go to the toilet) and functional limitations (eg, standing or bending).[4 5] Our results of higher number of chronic conditions and higher morbidity score among people aged 50–60 years in 2004–2010 than in 1992–1998 are consistent with this evidence. Importantly, some of the conditions we studied, such as hypertension, could be affected by screening and use of medication leading to higher prevalence in recent times (table 2). In the case of hypertension, for example, higher use of medication could stop the progression of the vascular condition are earlier stages leading to less detrimental health consequences (a result consistent with the hypothesis of dynamic equilibrium).[20] This may explain why there is no significant difference in prevalence of stroke between these cohorts (table 1).

Other research, however, indicates that disability is increasingly compressed within the past 2 years before death.[11 17] Our results are inconsistent with this evidence as we find no significant differences in a morbidity score between those who die in 1998–2004 and 2004–2010 in any of the three waves prior to death (roughly in the prior 2, 4 and 6 years before death). Contrary to what we may expect from the compression of morbidity hypothesis, this result implies a greater morbidity among those who die in recent times as they experienced higher prevalence of chronic conditions in periods prior to death, especially those conditions that impart very low mortality risk but have a high disease burden such as arthritis.

Limitations

This study has some limitations. First, we only used self-reported chronic disease because HRS does not have measured markers of health for the cohorts studied. While self-reported conditions may underestimate the actual prevalence of disease, the conditions we study have been shown to be accurately reported.[21 22] Second, for the retrospective sample we assessed chronic disease in the three waves prior to death, but do not estimate the exact time from death to each wave. Finally, we could not assess dementia, an important condition associated with disability, because there is no comparable criteria in HRS for the cohorts studied.

CONCLUSION

Using the largest longitudinal ageing study in the USA—the HRS—we study compression of morbidity prospectively, using two age-matched cohorts, and retrospectively, comparing the health status of two cohorts who die in 1998–2004 and 2004–2010, and found no clear evidence of compression of morbidity when morbidity is measured by self-reported chronic disease. A prospective assessment shows that older adults aged 51–61 years have significantly higher prevalence of major chronic conditions in recent times, while a retrospective

What is already known on this subject

As life expectancy continues to increase in most high-income countries, there is mixed evidence of whether additional years of life associate with lower time spent in morbidity.

What this study adds

- This study finds no clear evidence of compression of morbidity as measured by self-reported chronic disease among older adults in the USA.
- On the contrary, older adults in the USA experienced greater disease burden in recent times: there was a higher number of chronic conditions and higher morbidity score among people aged 50–60 years in 2004–2010 than in 1992–1998.
- There was also greater morbidity among those who die in recent times (2004–2010 vs 1998–2004) as they experienced higher prevalence of chronic conditions in the time period before death, especially those conditions that impart very low mortality risk but have a high disease burden such as arthritis.

evaluation indicates that those who die in recent times have significantly higher prevalence of most chronic conditions prior to death than did their counterparts who died in 1998–2004. As populations in most developed countries are becoming older, it is imperative to assess their health status.

Contributors HB-S conceptualised the study, designed and assisted the data analysis, and wrote the first version of the paper. MPJ conducted the data analysis, assisted with the interpretation of results, and reviewed the manuscript. SVS reviewed the manuscript.

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Competing interests None declared.

Ethics approval The Harvard University institutional review board approved the study.

Provenance and peer review Not commissioned; externally peer reviewed.

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