Ageing 3

Health, functioning, and disability in older adults—present status and future implications

Somnath Chatterji, Julie Byles, David Cutler, Teresa Seeman, Emese Verdes

Ageing is a dynamic process, and trends in the health status of older adults aged at least 60 years vary over time because of several factors. We examined reported trends in morbidity and mortality in older adults during the past two decades to identify patterns of ageing across the world. We showed some evidence for compression of morbidity (ie, a reduced amount of time spent in worse health), in four types of studies: 1) of good quality based on assessment criteria scores; 2) those in which a disability-related or impairment-related measure of morbidity was used; 3) longitudinal studies; or 4) studies undertaken in the USA and other high-income countries. Many studies, however, reported contrasting evidence (ie, for an expansion of morbidity), but with different methods, these measures are not directly comparable. Expansion of morbidity was more common when trends in chronic disease prevalence were studied. Our secondary analysis of data from longitudinal ageing surveys presents similar results. However, patterns of limitations in functioning vary substantially between countries and within countries over time, with no discernible explanation. Data from low-income countries are very sparse, and efforts to obtain information about the health of older adults in less-developed regions of the world are urgently needed. We especially need studies that focus on refining measurements of health, functioning, and disability in older people, with a core set of domains of functioning, that investigate the effects of these evolving patterns on the health-care system and their economic implications.

Lancet 2015; 385: 563–75

Published Online
November 6, 2014
http://dx.doi.org/10.1016/S0140-6736(14)61462-8

See Comment page 484

This online publication has been corrected. The corrected version first appeared at thelancet.com on February 6, 2015

See Online/Comment
http://dx.doi.org/10.1016/S0140-6736(14)61595-6 and
http://dx.doi.org/10.1016/S0140-6736(14)61596-8

See Online/Series
http://dx.doi.org/10.1016/S0140-6736(14)61347-7,
http://dx.doi.org/10.1016/S0140-6736(13)61489-0, and
http://dx.doi.org/10.1016/S0140-6736(14)61464-1

See Online/Viewpoint
http://dx.doi.org/10.1016/S0140-6736(14)61461-6

This is the third in a Series of five papers about ageing

Surveys, Measurement, and Analysis, Health Statistics and Information Systems, WHO, Geneva, Switzerland (S Chatterji MD, E Verdes PhD); **Research Centre for Gender**

Introduction

Demographic projections suggest that the populations of all countries are ageing, which will have wide-ranging effects on social, economical, and health systems. The world's population aged 60 years and older is set to rise from 841 million in 2013, to more than 2 billion by 2050, and exceed the number of children by 2047. By 2050, 21·1% of the world population will be 60 years or older, and 80% of this demographic group will live in low-income and middle-income countries, compared with about two-thirds at present. During the same period, global life expectancies are predicted to rise, reaching 83 years in high-income regions and 75 years in low-income and middle-income regions by 2045–50; when compared with life expectancy figures for 2010–15, the gap between life expectancies in more developed and less developed world regions is expected to narrow.[1] The population aged 60 years and older in less-developed regions is projected to rise from 554 million in 2013 to nearly 1·6 billion by 2050, because the annual growth rate of this section of the population in these regions is almost three times that in more-developed regions of the world. This growth in the older population is taking place in parallel with increasing inequalities in income, disparities in access to health care and social-support systems, and widening health gaps as a result of complex patterns of disease burden and globalisation of health risks. In most developing countries, these issues are compounded by a lifetime of accumulated health risks associated with poverty and inadequate access to health care. The changing epidemiological profiles in low-income and middle-income countries are largely driven by a set of conditions, such as rapid urbanisation, and changing dietary habits and levels of physical activity, that are different from those that were prevailing when these shifts in profiles happened in the high-income countries. Older populations are showing an increase in the incidence and prevalence of chronic non-communicable diseases that occur before the onset of old age with a natural history that takes place in conditions of poverty—these have been referred to as post-transitional illnesses in pretransitional circumstances.

In view of these trends, there has been much speculation about the health that this ageing cohort will have, such as: will the years gained be productive and healthy, or will elderly people live longer lives in conditions of ill health? Three main hypotheses have

Key messages

- Populations are rapidly ageing worldwide with major implications for health systems. This situation is more prevalent in low-income and middle-income countries
- A key question is whether older generations will be healthier than those who have preceded them. In other words, will we be adding life to years as populations age by ensuring maintained functioning and wellbeing?
- High-income countries show some evidence that a compression of morbidity (a reduction over time in the total lifetime days of disability) is taking place, as noted from trends of functioning and disability status. However, uncertainty remains about the health of future older generations in view of the different risk factor exposures in different cohorts and increases in the prevalence of chronic diseases
- Low-income and middle-income countries currently have no reliable evidence of compression, and morbidity might even be expanding, driven by lifestyle risk factors and increasing prevalence of chronic diseases
- In view of the shortage of data, robust evidence needs to be generated about these trends to ensure an appropriate response from health and social systems

Health and Ageing, University of Newcastle, Callaghan, NSW, Australia (Prof J Byles PhD); **Department of Economics and Kennedy School of Government, Harvard University, Cambridge MA, USA** (Prof D Cutler PhD); **Division of Geriatrics, David Geffen School of Medicine at University of California, Los Angeles CA, USA** (Prof T Seeman PhD)

Correspondence to: Dr Somnath Chatterji, WHO, Measurement and Health Information Systems, Geneva CH 1211, Switzerland **chatterjis@who.int**

been proposed to address this question.[2] The compression of morbidity hypothesis posits a situation for which the age of onset of morbidity is delayed to a greater extent than life expectancy rises, thereby compressing morbidity into a short period at a late age.[3] The expansion of morbidity hypothesis maintains the opposite, that increases in life expectancy are matched or exceeded by added periods of morbidity.[4] Both compression and expansion of morbidity could happen in absolute or relative terms—ie, changes in the absolute number of years lived with disability—or in terms of healthy life expectancy as a proportion of total life expectancy.

Healthy life expectancy is a measure that combines mortality and morbidity information in one index, expressing the number of healthy years of life lost because of poor health, and incorporating a range of severities to quantify poor health, which are based on different weights being assigned to different severity levels of disability that have resulted from various disorders. Data from the Global Burden of Disease 2010 study[5] show that from 1990 to 2010, as life expectancy rose healthy life expectancy increased more slowly, and little progress was made in the reduction of the non-fatal health effects of diseases. For example, during this period, men aged 50 years had a healthy life expectancy increase of 0·75 years for each year of increase in life expectancy. The corresponding rise in healthy life expectancy for women aged 50 years was 0·77 years. Although total life expectancy in Japanese women—currently the highest in the world with also some of the lowest disability levels in the world—increased by 3·9 years, healthy life expectancy increased only by 3·2 years during the same period.[5]

Evidence for the theory of equilibrium of morbidity lends support to a more multidimensional perspective, for which lessened progression and severity of morbidity are accompanied by rises in moderate or mild morbidity.[6] Data suggest that although severe disability-free life expectancies might have decreased in some high-income countries during the past four decades, total disability-free life expectancy has stagnated.[7] In fact, in older adults, morbidity might have expanded.[8] Health interventions that are targeted at lethal diseases could lead to increased years spent with a disability, which suggests that dissemination and uptake of lifestyle change interventions that reduce risk across a range of chronic disorders are essential. The coexistence of many diseases in an individual could mean that when mortality due to one disorder is prevented, disability due to another might become increasingly important.

Although life expectancy is clearly rising, the patterns of increase have not been consistent, with variable surges and periods of stagnation.[9] Whether gains in life expectancy will occur at a diminishing rate, or continue indefinitely, is under debate.[6] Investigators of studies of morbidity trends have drawn conflicting conclusions, and the quality of studies themselves are subject to several design and contextual factors, including the definition of morbidity, period studied, and study population.[9,10] Several review studies from high-income country settings have reported a fall in disability during the past few decades,[3,11,12] with concurrent increases in prevalence of chronic diseases;[13–16] however, these studies did not contain evidence from people aged 85 years and older.[9]

By contrast, in 2007, a review by the international Organisation for Economic Cooperation and Development (OECD) that used disparate data reported by countries, showed that although there is clear evidence of a reduction in disability in elderly people in five of the 12 countries studied, in other countries rates are increasing or stable. Although prevalence of most of these disorders and risk factors has increased, no clear judgment could be made about the link between chronic disorders and severe disabilities. The OECD investigation relied on a proxy operationalisation of severe disability— namely, one that was most clearly consistent with the available national, self-report, survey data, and was intuitively linked to long-term care needs. The study investigators concluded that "it would not seem prudent for policy makers to count on future reductions in the prevalence of severe disability in elderly people, but rather to expand national capacity in long-term care and programmes to prevent or postpone chronic conditions".

The situation in low-income and middle-income countries is much less studied, with very few data available. Delineation of the path of health and morbidity in old age has important implications for public health and the economy in terms of aspects of medical spending,[17] planning of social programmes,[18] prediction of trends in the workforce,[18] and the social patterning of poverty.[19]

We identified data for this Series paper, by searches of PubMed (Medline) and CABI Global Health Database on June 17, 2011. We used four classifications of search words, relating to older age; morbidity, activities of daily living, disability, impairment, length of hospital stay, chronic disease, and health status; life expectancy, and actuarial analysis; and trends. Only articles published in English between 1991 to present were included. Specifically, we aimed to answer these questions: have there been changes in the age of onset or severity of late-life morbidity, in relation to life expectancy? Which hypotheses of health and ageing trends have been supported by published work?

Second, we also undertook new analyses of publicly available crossnational datasets that contain harmonised items related to the health status of older adults during many periods. In these analyses we addressed several related questions—has the proportion of older adults with a disability remained stable, increased, or reduced over time? Is this change due to the effects of age or is it a cohort effect? What are the factors that affect these longitudinal trends? And how do these patterns compare

across countries? We used data from all the years that are available for public use.

We focused our analysis on trends in functioning in older adults because the review by Prince and colleagues in this Series[20] addresses the issue of trends in chronic diseases in far greater detail. An analysis of data from the Global Burden of Disease study[5] shows that nearly a quarter of all disease burden globally is carried by those aged 60 years and older, and that the per person burden is higher in developing countries, driven mainly by cardiovascular and respiratory diseases, and sensory impairments.

Trends in morbidity

The major issues when trying to understand levels and trends in the health of older adults are the absence of a common definition of health and understanding its constructs, and the need for a subsequent measurement of health in a way that is similar over time and across populations.

Health and social surveys rely heavily on self-reported measures. Self-reported health statistics have been traditionally measured in the older population with three main strategies. The first approach is to ask respondents a question about overall health that uses a 5-point rating scale ranging from very good to very bad (or from excellent to poor). Although this overall rating of health was associated with future mortality in cohort studies, what dimensions of health this question captures and whether it produces inconsistent patterns in population level studies across all ages, is not clear. This absence of clarity has led to a second strategy of investigators asking many questions across a small set of several domains that are believed to capture most of the variance in health states across population groups. The third strategy, frequently used in ageing studies, is a set of questions that measure functional independence by asking about activities of daily living (ADLs), such as bathing and dressing, and instrumental activities of daily living (IADLs), such as shopping or managing one's finances. Counts of ADLs and IADLs are then used to quantify health states and measure changes over time.

Similar measurements of health states are essential to examine relations between levels of health and other aspects such as future non-fatal health outcomes, risk factor profiles, and causes of death. To address this issue, WHO has defined a health state as a multidimensional attribute of an individual that shows his or her stages of the various domains of health at a specific point in time, and differs from pathological changes, risk factors, causes, health service encounters, or interventions. All societies have an intuitive notion of being in a good state of health that allows us to make statements such as individual A is in a better state of health than individual B. Non-fatal aspects of an individual's health state have been the focus of a many studies published in the past three decades, and have been incorporated into national and international health statistics such as the regular reporting by WHO of Disability-Adjusted Life-Years (DALYs) and healthy life expectancies (HALE), which are essentially individual health states aggregated to population levels.

Within the framework of WHO's International Classification of Functioning, Disability, and Health (ICF),[21] an individual's health state is understood as a vector of capacities to function in a set of domains that range from hearing, seeing, and moving around, to cognition and affect. An individual's capacity to function in a domain of health is, therefore, their intrinsic ability to do so irrespective of any environmental barriers or facilitators that might be in place in a real-life situation. This notion of capacity corresponds with the common-sense interpretation of health—an attribute of an individual, not of their environment. Different environments will admittedly have a substantial affect on the way the health state is experienced in an individual's actual environment, but that is not the individual's health per se. For the aim of measurement, domains of health need to be reduced to a small set that captures most of the variations, and estimates the respondents' intuitive notion of health. Measurement from these different domains should be combined into one metric of functioning that ranges from good functioning (good health) to difficulties in functioning (disability or poor health) that can then be compared across populations and over time. This combination also allows the direct comparison of health states across many diseases.[22]

This idea preserves the spirit of the WHO Constitution's definition of health. It does not equate health with diseases or diagnostic classifications, but recognises a chain through which risk factors and environmental factors are determinants of diseases, and diseases and environmental factors, in turn, are determinants of health states. A small but comprehensive set of domains as the basis for descriptions of health states allows detailed data collection for key components of individual health, and provides a basis for description and measurement of health states, and for undertaking an analysis of determinants of those states, including risk factors and environmental factors. A choice of domains in studies means that comparisons are possible only across studies of specific areas of functioning such as cognition or mobility, or for a small subset of measures such as ADLs or IADLs. A set of domains that spans physical, cognitive, and affective aspects of functioning has been used by WHO for its population surveys during the past decade.[23,24]

A similar set has been developed for use in health-interview surveys by the Budapest Initiative of the UN Economic Commission for Europe, and used in European and American surveys.[25] Although a common set of domains for use across international studies is helpful for comparisons, long-running, national, longitudinal studies also need comparisons of trends over time within

their respective surveys and therefore they maintain existing questions. Hence, addition of a subset of common domains to these studies would allow comparability with international efforts through the development of a robust, domain-based summary measure, without the loss of the important ability to examine changes over time within a specific survey.

Up to now, however, the specialty has not had a gold standard approach to creating one metric of health. Different strategies have been used to try to create one metric of health by combining the capacities in the different domains. These strategies have either used the assessment of different health states by individuals themselves, and used this assessment to create a cardinal scale of health, or used different psychometric approaches to combine information from the different domains with either classic test approaches such as factor analysis, or modern psychometric techniques based on the item response theory (IRT).[23,26] Attempts have also been made to address difficulties in comparability that surround self-reported health in surveys by use of anchoring vignettes to detect and correct for systematic biases in reporting.[27] This use of different statistical approaches to create one composite measure of health makes comparison across studies difficult.

Studies across the world do not offer consistent support for any one of the three postulated theories (compression, expansion, or equilibrium of morbidity). Many studies have reported some evidence for compression of morbidity,[8,28–33] and several others have reported some evidence for expansion of morbidity.[28,34–39] Of the 12 studies that have addressed more than one level of severity in decrements in health, five lent support to the theory of equilibrium of morbidity.[7,40–43] Several studies reported inconclusive or variable results.[28,44–46]

Researchers of one review concluded that the issue of whether rises in life expectancies across the world, especially in oldest old people aged at least 80 years, have been accompanied by a postponement of disability, is still open.[9] Although studies in most high-income countries have generally tended to suggest that most indices of ADL are improving, there has been some conflicting evidence. An investigation in Spain reported consistent worsening in an index of ADLs over time, more so for women than for men.[32] Additionally, a study in Sweden has reported increases in ADLs during the past two decades.[47]

Patterns of morbidity-free life expectancies have varied according to the definition of morbidity used in different studies. Disability-related or impairment-related measures of morbidity, functional limitation, discomfort, or activity restriction, have been the most widely studied. Morbidity is most often self-reported, although, increasingly, studies of ageing have also begun to incorporate performance-based measures,[43] and have at times reported severe disability identified by a medical expert.[31] Of the studies that defined morbidity as a form of disability or impairment, twice as many contain evidence to support compression of morbidity[8,28–33,40,42,48] than expansion.[28,34,35,49,50] Four of the studies reviewed offered support for equilibrium of morbidity, and five had inconclusive results. Three studies have reported data that span a long time—more than 20 years.[28–30]

Many studies have quantified morbidity-free life expectancy by the absence of major chronic diseases; seven of the studies reviewed looked at many diseases or disease clusters,[33,37,42,44–46,48] and two looked at one major chronic disease.[39,49] Three of the seven studies examining several diseases reported evidence for expansion of morbidity, and none lent support to the theory of a compression of morbidity, dependant on how morbidity was defined. Most notably, in the Netherlands[37] between 1989 and 2000, life expectancy without chronic diseases diminished significantly, more so for women. The gap in 1989 was 0·6 years, and women had longer, disease-free lives, whereas in 2000 the gap was 2·9 years and men had longer lives free from chronic diseases. In Denmark,[48] a rise in total life expectancy between 1987 and 2000 was accompanied by an absolute decrease in disability-free life expectancy in people aged 65 years and older, suggesting an improvement in their health status. However, life expectancy with chronic illnesses showed little change for older adults, with some increase in cardiovascular diseases in men. Two studies that looked at one disease reported patterns of expansion of morbidity for cancer,[39] and a rise in stroke prevalence,[49] but also noted improvements in stroke recovery and cure rates for cancer. Only one study investigated disease severity (limiting *vs* non-limiting illness), and reported equilibrium of morbidity.[42] Five studies had inconclusive or variable results, including sex-specific[33,44,45] or disease-specific[46] variance. Studies that adopt indirect indicators of morbidity such as age at first admission to hospital[36] and patterns in the need for long-term care,[31] reported a pattern of expansion and compression, respectively.

Geographically, studies of populations within European countries provide conflicting evidence, offering equal support for either compression or expansion of morbidity. Studies from Asian countries have not reported evidence for compression of morbidity[51,52]—two have shown some evidence for expansion but most from the region show variable results. Evidence for compression of morbidity (as disability) has been reported by many investigators in the USA. A longitudinal study that explored stroke prevalence in China, suggested expansion of morbidity with respect to disability-free life expectancy.[49] 12 studies reviewed included two or more classifications of morbidity severity, and could thus test the equilibrium of morbidity hypothesis. All studies reported trends of increasing total life expectancy. Five lent support to the theory of equilibrium of morbidity, and defined morbidity according to disability,[7,40,43] functional limitation,[41] and illness or limiting illness.[42]

Data from the USA and Europe provide further evidence and have addressed specific questions about decreases in specific domains of functioning. An analysis of data from the USA suggested that risks associated with diseases of older adults such as obesity and inflammation are increasing.[53] Although survival with cardiovascular disease and cancers might have improved, no evidence exists that their incidence is actually decreasing, and musculoskeletal disorders and arthritis have been increasing. Furthermore, this investigation showed that there has been an expansion of life with disease, and with limitations in mobility functioning. Several other studies have also suggested that disabilities might be increasing in new cohorts of older adults. By use of newer forecasting methods, some investigators have concluded that the increasing trends in obesity prevalence in the USA will probably not only reduce life-expectancy gains, but also substantially increase morbidity and worsen health outcomes in future cohorts because of related disorders such as diabetes and cardiovascular disease.[53]

A study examining cognitive impairment in two cohorts of older adults aged 70 years and older in 1993 and 2002, respectively, showed that the 2002 cohort had fewer IADLs limitations but higher rates of hypertension, obesity, diabetes, and heart disease than did the 1993 cohort. The proportion of people with cognitive impairment was lower (8·7%) in the 2002 cohort than in the 1993 cohort (12·2%). Results from multivariable analyses showed that increasing levels of education and net monetary worth in the older population accounted for a large part of this difference, which lends support to the cognitive-reserve hypothesis. This result led the investigators to conclude that, although the risks had increased over time, early identification and more effective treatment had perhaps prevented a deterioration in cognitive function. However, the assessment of trends in cognition with longitudinal data poses a challenge because respondents could learn how to do the tests over time and the effect could compensate for deteriorations in cognitive performance.[54] Additionally, missing data for

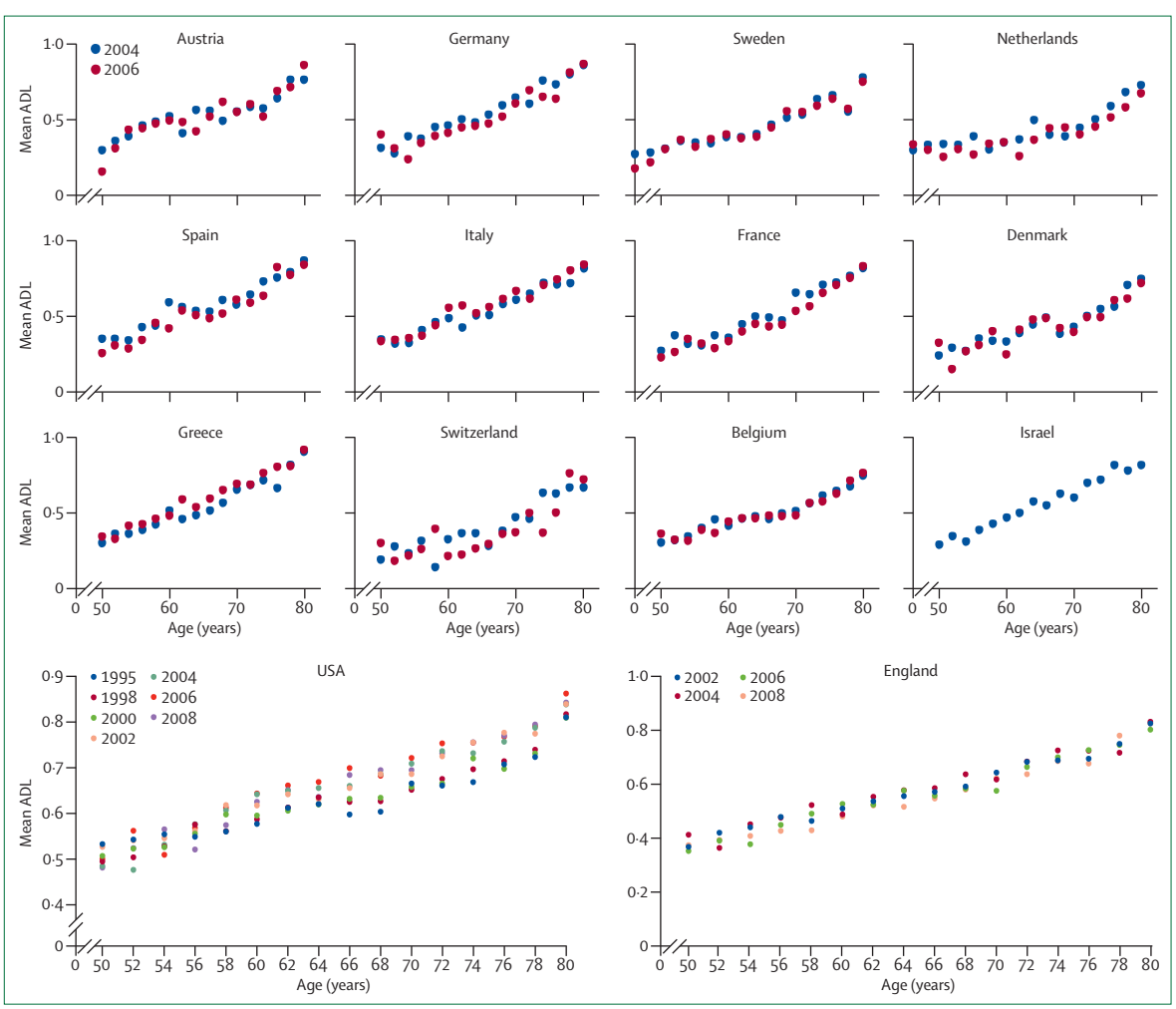

Figure 1: **ADL limitations by country, age, and time**
Data taken from SHARE.[55] SHARE=The Survey of Health, Ageing and Retirement in Europe. ADL=activities of daily living.

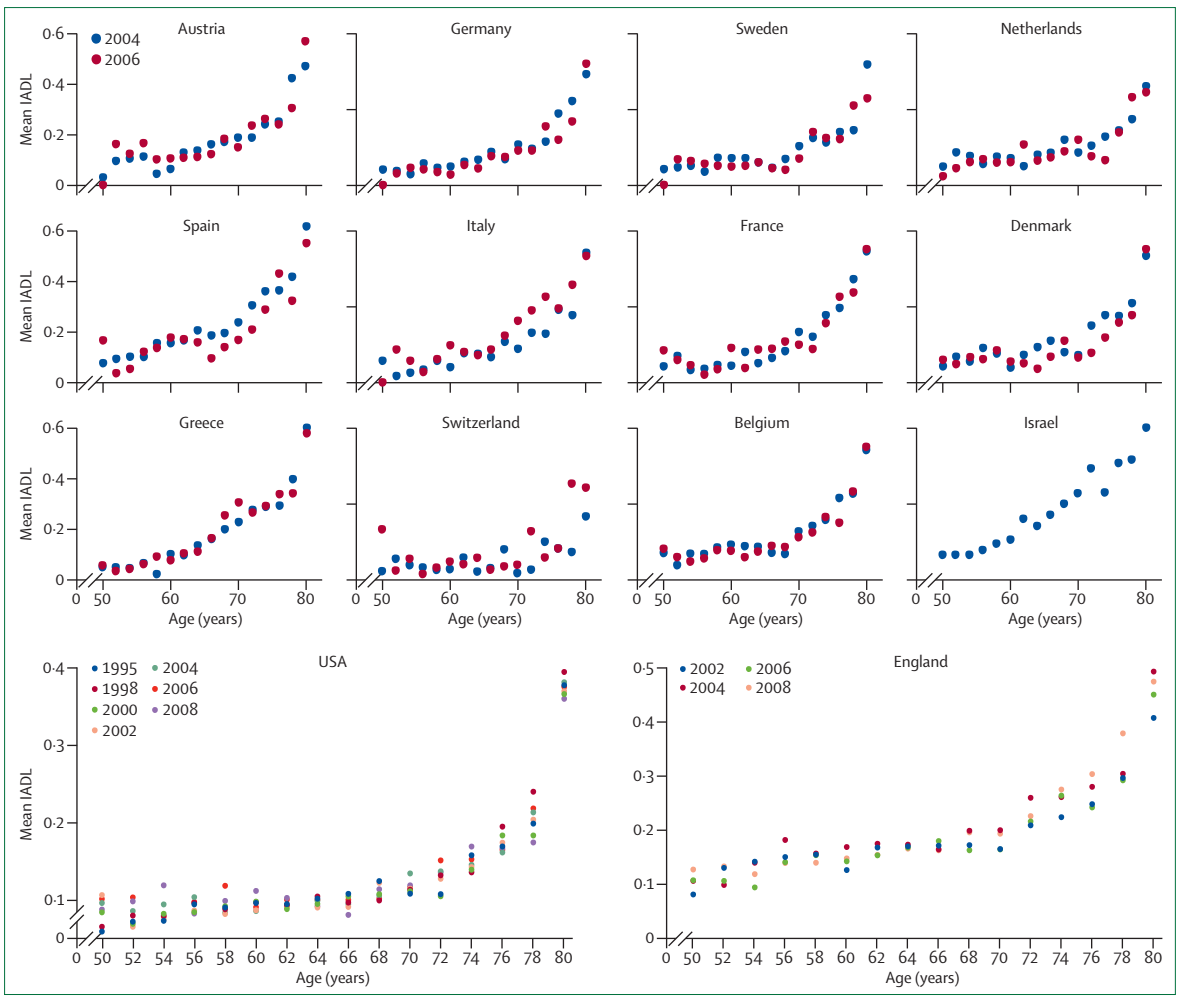

Figure 2: **IADL limitations by country, age, and time**
Data taken from SHARE.[55] SHARE=The Survey of Health, Ageing and Retirement in Europe. IADL=instrumental activities of daily living.

respondents who become severely cognitively impaired (eg, from stroke or dementia), or those lost to follow-up because of death or other reasons, poses a challenge.

Analyses of longitudinal studies

We have undertaken an analysis of several longitudinal studies of ageing and of cross-sectional analysis of a large dataset from the World Health Surveys as described in the appendix. Across all countries in the surveys, the proportion of respondents with ADL limitations shows a steady rise with age. However, this increase is substantial between the ages of 50 and 70 years in countries like Greece, Spain, and Italy, compared with countries such as the Netherlands, Sweden, and Switzerland where these increases seem to happen predominantly in those older than 70 years. The steady gradient is also seen in the USA and England.

See Online for appendix

During the two waves of the Survey of Health, Ageing and Retirement in Europe study (SHARE),[55] in most countries studied, the proportion of respondents with ADL limitations across age groups seems to have stayed fairly constant. In the USA these proportions have steadily increased since 1995 across all age groups. However, in England, these proportions decreased during the period of the survey across all respondents except the most elderly people (figure 1).

The proportion of respondents with IADL limitations was consistently lower than those with ADL limitations in all countries. This result was not surprising, in view of the typical hierarchy of ADLs as the most severe and least common form of disability, when compared with IADL disabilities, and to a greater extent, physical functional limitations (which are the least severe and most common). The age patterns of IADLs across age groups and countries were very similar to those of ADL limitations: a steady rise in the proportion with IADL limitations with age in most countries except the Netherlands, Sweden, and Switzerland (in these countries, increases were predominantly in people older than 70 years).

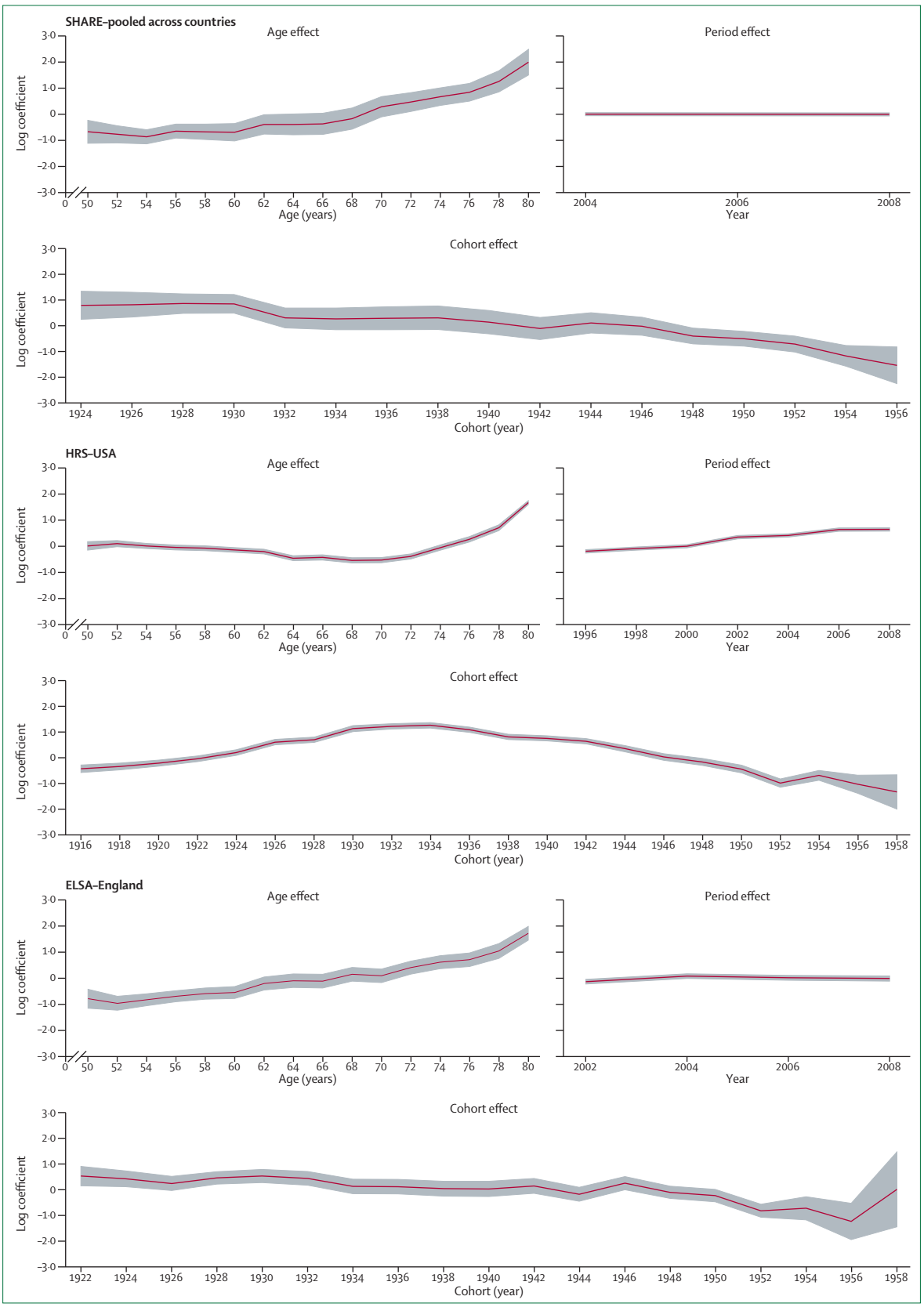

***Figure 3*: Age-period-cohort effects for ADL limitations by survey**[55-57]
ADL=activities of daily living. SHARE=The Survey of Health, Ageing and Retirement in Europe. HRS=The Health and Retirement Study. ELSA=The English Longitudinal Study of Ageing.

As with ADL limitations, a larger proportion of respondents in Italy reported limitations in IADLs across all ages in the second wave than in the first wave, whereas this proportion decreased in Spain during the two waves of the investigation; all other countries showed little change between the two waves. In the USA the proportion of this population reduced over time, especially in people aged 75 years and older); however, in England the pattern seemed to be the reverse with increases in these proportions over time, more so in the most elderly people (figure 2).

Analysis of age, period, and cohort effects across the different studies shows a very strong linear effect, with a clear trend of increasing disability with age. However, although this trend is consistently noted in people older than 50 years in the SHARE countries and in England, in the USA it was apparent only in those older than 70 years. The cohort effects show that in the SHARE countries, levels of ADL limitations have been falling steadily across consecutive cohorts and have continued to do so up to the most recent cohorts included in the study. In the USA ADL limitations steadily rose until measured in people born in 1935, and began falling thereafter with a suggestion of a rise again in the cohort born between 1952 and 1954, although not to the levels of those born around 1935. By contrast, in England, the levels of ADL disability seem to have remained more or less constant in cohorts born since the 1920s, with some suggestion of a cohort effect with increases in ADL limitations in 1942 and 1946 (figure 3).

The results for IADLs were more consistent across studies, with an age effect evident across all countries only in people older than 70 years, with steady rises in IADL limitations thereafter. There are no evident cohort effects in any of the studies (figure 4).

We did longitudinal analyses of these datasets with a generalised estimating equation model. In the Health and Retirement Study (HRS), English Longitudinal Study of Ageing (ELSA), and SHARE study[55–57] across all age groups, the likelihood of development of disabilities, as measured by ADL and IADL limitations, rose with each wave. Women were also more likely to develop disabilities than men (appendix).

To compare these results with those from low-income and middle-income countries, we analysed data from the 10/66 group of studies.[58] The study sample consisted of community-residing individuals aged 65 years and older in Cuba, Dominican Republic, Peru, Mexico, Venezuela, Puerto Rico, China, and India. Two waves of data from 2003 and 2007 were available. We used a score derived from the measure of disability, the WHO Disability Assessment Schedule version 2.0, to compare changes in disability over time. Our analysis showed that in these countries, consistent with our analysis of other surveys and across all sites, the health of women worsened significantly more than that of men, as did the health of those with poorer education and increasing age.

Finally, our cross-sectional analysis of data from the World Health Surveys showed that health status fell as the population grew older, with a substantial fall in the most elderly group. This reduction in health is greater in low-income than high-income countries. Further examination of worsening health by socioeconomic status shows that the magnitude of age-related reductions was the same across wealth quintiles in low-income countries, whereas in high-income countries health worsened far more rapidly in the poorest quintiles, compared with the richest section of the population. The health status of older adults in the poorest quintiles was at least a decade behind that of older adults in the richest quintile. Of interest is our finding that the health of the poorest quintile of the population in high-income countries was similar to the health of the upper-income population from low-income countries.

Analysis of this dataset also showed that people with the least education or wealth had the worst health. Further examination showed that this difference in health was significant in the domains of mobility, self-care, pain, cognition, interpersonal activity, and vision. Inequalities in the different domains of health were higher in high-income countries than in low-income countries.

Implications for the future and possible interventions

Our systematic examination of the scientific literature shows that support for morbidity pattern hypotheses varies mainly according to the type of health indicator. Disability-related or impairment-related measures of morbidity tend to support the theory of compression of morbidity, whereas chronic disease morbidity tends to support the expansion of morbidity hypothesis. Parker and Thorslund[59] previously reported similar patterns in a review.

A simplified view of population-health change progresses through the following stages: risk factors → diseases or disorders → loss of function → disability → death.[10] Our findings suggest that loss of functioning and disability during a lifecourse might be improving. This improvement might be attributed to advances in rehabilitative medicine, modifications to physical living environments, or to education and positive early-life experiences.[60] By contrast, morbidity as chronic disease, at the other end of the range, could be worsening (although few studies reported data for this dimension of morbidity). The extent to which this occurrence is a product of heightened awareness of diseases versus actual disease increase is probably disease-dependent and setting-dependent. Our investigation did not encompass trends in risk factors, which could be worsening (in the case of obesity and sedentary lifestyles) or improving (in the case of tobacco use).[3] Equilibrium of morbidity might also be roughly placed within this range, with more severe disability positioned to the right, and less severe disability to the left. In studies that assessed

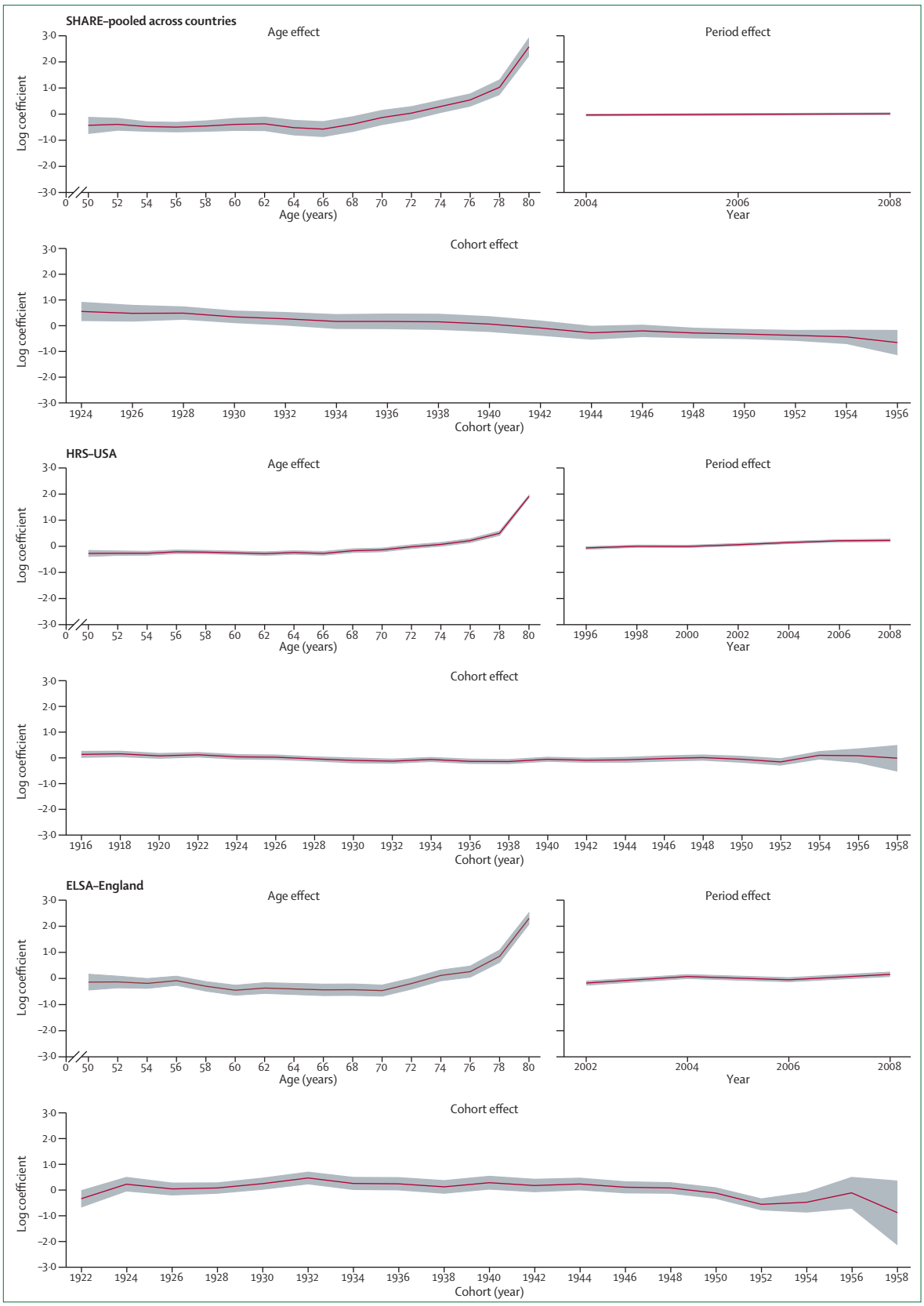

***Figure 4*: Age-period-cohort effects for IADL limitations by survey**[55-57]
IADL=instrumental activities of daily living. SHARE=The Survey of Health, Ageing and Retirement in Europe. HRS=The Health and Retirement Study. ELSA=The English Longitudinal Study of Ageing.

morbidity severity, we did not find predominating evidence for any one hypothesis about health and ageing.

Possible trends according to geography and study design were detected, although these could be partly attributed to differing morbidity definitions. Cambois and colleagues,[28] for example, have showed the importance of consistent definition of the morbidity constructs, because four different health surveys in France had similar findings for a range of morbidity indicators, when consistent definitions were used across the different data sources. On one hand, studies from the USA suggest compression of morbidity, but all these studies reported morbidity as disability and thus whether the USA had similar patterns for other measures of morbidity is unclear. Data from Asian countries, on the other hand, showed an expansion of morbidity more often than compression (with disability measures), but results were largely inconclusive or variable. Regrettably, the studies included in our review did not adequately represent low-income countries. The strengthening of data collection and epidemiological research capacity within these settings is fundamental to improved understanding of health and ageing trends, because data from more developed countries might not be relevant to developing countries. For example, a shifting disease burden from infectious to chronic diseases implies a change in the patterns of illness and disability within populations.[61]

The use of prevalence-based lifetables (mainly by cross-sectional studies) enabled the detection of shifting health patterns in the long term. Prevalence-based life tables are less sensitive to dynamic health states with many morbidity-related transitions.[62,63] Nearly 70% of the reviewed studies were cross-sectional, reporting mixed support for the three hypotheses according to various health indicators. This result was not surprising, because specific diseases or disorders could have characteristic progression patterns.[61] Multistate life tables, which can be used with longitudinal data, have the advantage of detecting transitions between stages of morbidity.[62] Longitudinal study designs tended to report compression of morbidity as disability, although there were few longitudinal data for other dimensions of morbidity. As more longitudinal data become available the development of advanced methods of analysis, such as multivariate stochastic process models, will help to delineate trends in dimensions of morbidity and mortality more accurately than at present.[64] Studies that analysed administrative data aligned closely with the trends reported by morbidity definition, finding compression of disability and expansion of chronic disease.

Preventive measures initiated early in life could be fundamental to negating expansion of morbidity later in life, or sustaining situations of morbidity compression. The studies reviewed suggested a possible expansion of chronic disease, with some support for expansion of disability-related or impairment-related morbidity. Health problems later in life had been previously linked to early life experiences, such as having risk factors for chronic diseases.[65,66] Because the direction of health and ageing trends in future years might be different from the present situation, continuing research through population surveys is justified to plan for and meet changing needs.

The shortage of studies from low-income and middle-income countries emphasises the need for population studies in such regions. Low-income and middle-income countries are predicted to have the greatest gains in life expectancy during the coming years;[1] epidemiological patterning of health trends will enable the ability to foresee and plan for changes in population health. Additionally, research that explores relations between various dimensions of morbidity is also warranted. Furthermore, detailed analyses of data that include life histories (including reproductive histories) will also be needed to understand the reasons why sex differences exist in these health trajectories. A decomposition analysis that addressed differences in disability between older men and women showed that a large part of these differences arise from social determinants such as education, employment, and economical and marital status.[67]

Discussion

Our analysis of three large longitudinal surveys of older adults with a harmonised assessment of disability with regard to ADL and IADL limitations, shows varied patterns. Not all countries show consistent evidence for a compression of morbidity. Italy, Spain, and Greece seem to have much larger proportions of people who are disabled across all ages, irrespective of the measure used. However, difficulties with IADLs seem to become more apparent in elderly respondents across all countries. Although consecutive cohorts seem to have steadily improved in health with respect to decreases in ADL limitations, limitations in IADLs did not improve. Additionally, in the USA and England, the apparent rise in ADL disability in cohorts from 1955 and 1944 needs to be watched over time. We chose not to undertake a meta-analysis in view of the very disparate outcomes used in the studies in the scientific literature and the different approaches to thinking about and constructing only one measure of health status.

To track the health of older adults over time and across populations, a common conceptual framework and approach to measurement is imperative. Present longitudinal studies of ageing are increasingly working towards an effort at harmonisation of these studies, such that a common set of measures are used in these disparate studies. A minimum subset of measures with standard approaches to implementation will go a long way to increase the robustness of these comparisons. Continuous measures of functioning capacity, coupled with measures of more severe levels of disability such as ADLs, will perhaps be in accordance in this respect.

Furthermore, incorporation of performance measures of functioning such as tests of cognition, gait speed, and grip strength, with measures of physiological risk such as raised body-mass index, increased waist-to-hip ratios, hypertension, hyperglycaemia, hyperlipidaemia, and raised inflammatory markers such as C-reactive protein will further the efforts at comparison of health outcomes in these populations. Thus, rather than focusing on trends in the prevalence of chronic diseases only, functioning-based assessments of health status (consisting of a core set of domains) need to become an integral part of national data collection efforts to monitor trends in healthy life expectancies, especially for older adults.

Expectations are that with early detection and intervention for a range of risk factors and chronic health disorders, an increasing number of individuals globally will live into old age (older than 60 years). Studies from the USA and Denmark suggest that about 30–40% of the most older people could live independently without much disability. This plateauing of disability in the most old people suggests that interventions to improve health in older adults are likely to pay dividends.

However, many of the causes of disability in later life are the result of accumulated lifestyle and other risks much earlier in life, so interventions should be directed at the reversal of trends in risks such as smoking and obesity at young ages for payoffs in the future; early interventions are also suggested by Prince and colleagues in their Series paper.[20] Increased physical activity, mental stimulation, and participation in leisure activities, coupled with early detection, might help to preserve cognitive function into old age. However, as noted by Beard and Bloom in their Viewpoint[68] these risks continue into old age and warrant continuous surveillance and interventions in older adults as well. Training strategies that could alter cognitive-behavioural styles of older adults to adapt to changing life circumstances might also help to keep them in good health in later life, by preserving their cognitive function as they age.

The key question is that as populations worldwide continue to live longer, will they stay in good health for those added years? An individual's health, irrespective of having a chronic illness, is defined by being able to execute series of day-to-day actions and tasks. The capacity to do this with as little difficulty as possible defines good health. As noted by Beard and Bloom, comprehensive assessments of functioning are needed since this approach to an individual's health is not only particularly relevant for older adults who might have many chronic illnesses, but they are also far improved predictors of survival than merely the presence of disease. Health interventions can then focus on improving the functioning of older adults within an integrated people-centred care strategy across the entire continuum of care.[69] As noted in the Comments by Rodriguez-Manas and Fried,[70] and Banerjee,[71] in this Series, drawing attention to the identification and management of the health of older adults as they grow frail with many chronic disorders is especially urgent.

Moreover, as Steptoe and colleagues[72] point out in their paper in this Series, the relation between health and subjective wellbeing is bidirectional. Older adults with chronic illnesses are likely to have reduced wellbeing. Subjective wellbeing is predictive of longer survival. Bloom and colleagues[73] emphasise in their review in this Series that the right economical, social, and health system policies coupled with changes in individual behaviour can ensure the future good health and wellbeing of older adults. As we add increasing years to life, we should also ensure that these years are spent in good health as far as possible, thereby keeping this burgeoning section of the population healthy, with preserved wellbeing.

Contributors

SC, TS, and EV designed the study. Data were obtained by SC, analysed by SC and EV, and interpreted by SC, JB, DC, and TS. The manuscript was written by all authors and reviewed by JB and DC.

Declaration of interests

This study was supported by the Division of Behavioural and Social Research at the US National Institute on Aging through Interagency Agreements (OGHA 04034785; YA1323–08-CN-0020; Y1-AG- 1005–01), and research grants (R01-AG034479 and R21-AG034263). The views expressed by SC and EV are theirs alone and not necessarily those of WHO.

Acknowledgments

We thank Linda Martin and Ties Boerma for their valuable comments on an earlier version of this manuscript, Nicole Bergen for research assistance, and Ties Boerma for valuable comments on drafts of this manuscript.

References

1 UN Department of Economic and Social Affairs Population Division. World Population Ageing 2013. New York; 2013.
2 Crimmins EM, Beltrán-Sánchez H. Mortality and morbidity trends: is there compression of morbidity? *J Gerontol B Psychol Sci Soc Sci* 2011; **66:** 75–86.
3 Fries JF. Measuring and monitoring success in compressing morbidity. *Ann Intern Med* 2003; **139:** 455–59.
4 Gruenberg EM. The failures of success. *Milbank Mem Fund Q Health Soc* 1977; **55:** 3–24.
5 Salomon JA, Wang H, Freeman MK, et al. Healthy life expectancy for 187 countries, 1990–2010: a systematic analysis for the Global Burden Disease Study 2010. *Lancet* 2012; **380:** 2144–62.
6 Manton KG. Changing concepts of morbidity and mortality in the elderly population. *Milbank Mem Fund Q Health Soc* 1982; **60:** 183–244.
7 Perenboom RJ, Van Herten LM, Boshuizen HC, Van Den Bos GA. Trends in disability-free life expectancy. *Disabil Rehabil* 2004; **26:** 377–86.
8 Crimmins EM, Hayward MD, Hagedorn A, Saito Y, Brouard N. Change in disability-free life expectancy for Americans 70-years-old and older. *Demography* 2009; **46:** 627–46.
9 Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. *Lancet* 2009; **374:** 1196–208.
10 Crimmins EM. Trends in the health of the elderly. *Annu Rev Public Health* 2004; **25:** 79–98.
11 Schoeni RF, Freedman VA, Wallace RB. Persistent, consistent, widespread, and robust? Another look at recent trends in old-age disability. *J Gerontol B Psychol Sci Soc Sci* 2001; **56:** S206–18.

12 Jacobzone S. Coping with aging: international challenges. *Health Aff (Millwood)* 2000; **19:** 213–25.

13 Payne G, Laporte A, Deber R, Coyte PC. Counting backward to health care's future: using time-to-death modeling to identify changes in end-of-life morbidity and the impact of aging on health care expenditures. *Milbank Q* 2007; **85:** 213–57.

14 Crimmins EM, Saito Y. Change in the Prevalence of Diseases among Older Americans: 1984-1994. *Demogr Res* 2000; **3**: 9.

15 Freedman VA, Martin LG. Contribution of chronic conditions to aggregate changes in old-age functioning. *Am J Public Health* 2000; **90:** 1755–60.

16 Freedman VA, Schoeni RF, Martin LG, Cornman JC. Chronic conditions and the decline in late-life disability. *Demography* 2007; **44:** 459–77.

17 Cutler DM. Declining disability among the elderly. *Health Aff (Millwood)* 2001; **20:** 11–27.

18 Crimmins EM, Reynolds SL, Saito Y. Trends in health and ability to work among the older working-age population. *J Gerontol B Psychol Sci Soc Sci* 1999; **54:** S31–40.

19 Diczfalusy E. The third age, the Third World and the third millennium. *Contraception* 1996; **53:** 1–7.

20 Prince M, Fan W, Guo G, et al. The burden of disease in older people; implications for health policy and practice. *Lancet* 2014; published online Nov 6. http://dx.doi.org/10.1016/S0140-6736(14)61347-7.

21 WHO. International classification of functioning, disability, and health. Geneva: World Health Organization; 2006.

22 Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. *Lancet* 2007; **370:** 851–58.

23 Salomon JA, Murray CJ, Ustun T, Chatterji S. Health state valuations in summary measures of population health. In: Murray CJ, Evans D, eds. Health System Performance Assessment: Debates, Methods and Empiricism.Geneva: World Health Organization; 2003.

24 Salomon JA, Mathers CD, Chatterji S, Sadana R, Ustun T, Murray CJ. Quantifying individual levels of health: definitions, concepts and measurement issues. In: Murray CJ, Evans D, editors. Health Systems Performance Assessment: Debates, Methods and Empiricism.Geneva: World Health Organization; 2003.

25 UN Economic Commission for Europe. Survey module for measuring health state. New York and Geneva: United Nations; 2012.

26 Wilson M, Allen DD, Li JC. Improving measurement in health education and health behavior research using item response modeling: introducing item response modeling. *Health Educ Res* 2006; **21** (suppl 1)**:** i4–18.

27 Murray CJ, Ozaltin E, Tandon A, Salomon JA, Sadana R, Chatterji S. Empirical evaluation of the anchoring vignette approach in health surveys. In: Murray CJ, Evans D, eds. Health System Performance Assessment: Debates, Methods and Empiricism.Geneva: World Health Organization; 2003.

28 Cambois E, Clavel A, Romieu I, Robine JM. Trends in disability-free life expectancy at age 65 in France: consistent and diverging patterns according to the underlying disability measure. *Eur J Ageing* 2008; **5:** 287–98.

29 Manton KG, Gu X, Lowrimore GR. Cohort changes in active life expectancy in the U.S. elderly population: experience from the 1982-2004 National Long-Term Care Survey. *J Gerontol B Psychol Sci Soc Sci* 2008; **63:** S269–81.

30 Moe JO, Hagen TP. Trends and variation in mild disability and functional limitations among older adults in Norway, 1986–2008. *Eur J Ageing* 2011; **8:** 49–61.

31 Pinheiro P, Krämer A. Calculation of health expectancies with administrative data for North Rhine-Westphalia, a Federal State of Germany, 1999-2005. *Popul Health Metr* 2009; **7:** 4.

32 Sagardui-Villamor J, Guallar-Castillón P, García-Ferruelo M, Banegas JR, Rodríguez-Artalejo F. Trends in disability and disability-free life expectancy among elderly people in Spain: 1986-1999. *J Gerontol A Biol Sci Med Sci* 2005; **60:** 1028–34.

33 Van Oyen H, Cox B, Demarest S, Deboosere P, Lorant V. Trends in health expectancy indicators in the older adult population in Belgium between 1997 and 2004. *Eur J Ageing* 2008; **5:** 137–46.

34 Hashimoto S, Kawado M, Seko R, et al. Trends in disability-free life expectancy in Japan, 1995-2004. *J Epidemiol* 2010; **20:** 308–12.

35 Kelly S, Baker A. Healthy life expectancy in Great Britain 1980–96 and its use as an indicator in United Kingdom government strategies. *Health Stat Q* 2000; **7:** 32–37.

36 Lynch C, Holman CD, Moorin RE. Use of Western Australian linked hospital morbidity and mortality data to explore theories of compression, expansion and dynamic equilibrium. *Aust Health Rev* 2007; **31:** 571–81.

37 Perenboom RJ, van Herten LM, Boshuizen HC, van den Bos GA. Life expectancy without chronic morbidity: trends in gender and socioeconomic disparities. *Public Health Rep* 2005; **120:** 46–54.

38 Breakwell C, Bajekal M. Health expectancies in the UK and its constituent countries, 2001. *Health Stat Q* 2006; **29:** 18–25.

39 Verdecchia A, Mariotto A, Capocaccia R, et al. Incidence and prevalence of all cancerous diseases in Italy: trends and implications. *Eur J Cancer* 2001; **37:** 1149–57.

40 Cai L, Lubitz J. Was there compression of disability for older Americans from 1992 to 2003? *Demography* 2007; **44:** 479–95.

41 Graham P, Blakely T, Davis P, Sporle A, Pearce N. Compression, expansion, or dynamic equilibrium? The evolution of health expectancy in New Zealand. *J Epidemiol Community Health* 2004; **58:** 659–66.

42 Jeune B, Bronnum-Hansen H. Trends in health expectancy at age 65 for various health indicators, 1987-2005, Denmark. *Eur J Ageing* 2008; **5:** 279–85.

43 Liu J, Chen G, Song X, Chi I, Zheng X. Trends in disability-free life expectancy among Chinese older adults. *J Aging Health* 2009; **21:** 266–85.

44 Brønnum-Hansen H. Trends in health expectancy in Denmark, 1987-1994. *Dan Med Bull* 1998; **45:** 217–21.

45 Gu D, Dupre ME, Warner DF, Zeng Y. Changing health status and health expectancies among older adults in China: gender differences from 1992 to 2002. *Soc Sci Med* 2009; **68:** 2170–79.

46 Jang SN, Kim DH. Trends in the health status of older Koreans. *J Am Geriatr Soc* 2010; **58:** 592–98.

47 Parker MG, Schön P, Lagergren M, Thorslund M. Functional ability in the elderly Swedish population from 1980 to 2005. *Eur J Ageing* 2008; **5:** 299–309.

48 Brønnum-Hansen H. Health expectancy in Denmark, 1987–2000. *Eur J Public Health* 2005; **15:** 20–25.

49 Fang XH, Zimmer Z, Kaneda T, Tang Z, Xiang MJ. Stroke and active life expectancy among older adults in Beijing, China. *Disabil Rehabil* 2009; **31:** 701–11.

50 Report: Health expectancies in the UK, 2002. *Health Stat Q* 2006; **29:** 59–62.

51 Schoeni RF, Liang J, Bennett J, Sugisawa H, Fukaya T, Kobayashi E. Trends in old-age functioning and disability in Japan, 1993–2002. *Popul Stud (Camb)* 2006; **60:** 39–53.

52 Martin LG, Zimmer Z, Hurng BS. Trends in late-life disability in Taiwan, 1989-2007: the roles of education, environment, and technology. *Popul Stud (Camb)* 2011; **65:** 289–304.

53 Reither EN, Olshansky SJ, Yang Y. New forecasting methodology indicates more disease and earlier mortality ahead for today's younger Americans. *Health Aff (Millwood)* 2011; **30:** 1562–68.

54 Langa KM, Larson EB, Karlawish JH, et al. Trends in the prevalence and mortality of cognitive impairment in the United States: is there evidence of a compression of cognitive morbidity? *Alzheimers Dement* 2008; **4:** 134–44.

55 SHARE: Survey of Health, Ageing, and Retirement in Europe. http://www.share-project.org/ (accessed Sept 8, 2014).

56 HRS: Health and Retirement Study. http://www.hrsonline.isr.umich.edu (accessed Sept 8, 2014).

57 ELSA: English Longitudinal Study of Ageing. http://www.elsa-project.ac.uk (accessed Sept 8, 2014).

58 Prince M, Ferri CP, Acosta D, et al. The protocols for the 10/66 dementia research group population-based research programme. *BMC Public Health* 2007; **7:** 165.

59 Parker MG, Thorslund M. Health trends in the elderly population: getting better and getting worse. *Gerontologist* 2007; **47:** 150–58.

60 Freedman VA, Martin LG, Schoeni RF. Recent trends in disability and functioning among older adults in the United States: a systematic review. *JAMA* 2002; **288:** 3137–46.

61 Crimmins EM, Saito Y. Trends in healthy life expectancy in the United States, 1970-1990: gender, racial, and educational differences. *Soc Sci Med* 2001; **52:** 1629–41.

62 Barendregt JJ, Bonneux L, Van der Maas PJ. Health expectancy: an indicator for change? Technology Assessment Methods Project Team. *J Epidemiol Community Health* 1994; **48:** 482–87.

63 Mathers CD, Robine JM. How good is Sullivan's method for monitoring changes in population health expectancies? *J Epidemiol Community Health* 1997; **51:** 80–86.

64 Manton KG. Dynamic paradigms for human mortality and aging. *J Gerontol A Biol Sci Med Sci* 1999; **54:** B247–54.

65 Hubert HB, Bloch DA, Oehlert JW, Fries JF. Lifestyle habits and compression of morbidity. *J Gerontol A Biol Sci Med Sci* 2002; **57:** M347–51.

66 Vita AJ, Terry RB, Hubert HB, Fries JF. Aging, health risks, and cumulative disability. *N Engl J Med* 1998; **338:** 1035–41.

67 Hosseinpoor AR, Williams JS, Jann B, et al. Social determinants of sex differences in disability among older adults: a multi-country decomposition analysis using the World Health Survey. *Int J Equity Health* 2012; **11:** 52.

68 Beard JR, Bloom DE. Towards a comprehensive public health response to population ageing. *Lancet* 2014; published Nov 6. http://dx.doi.org/10.1016/S0140-6736(14)61461-6.

69 WHO. WHO strategy on people-centred and integrated health services. Draft for Consultation. Geneva: World Health Organization; 2014.

70 Rodriguez-Mañas L, Fried LP. Frailty in the clinical scenario. *Lancet* 2014; published online Nov 6. http://dx.doi.org/10.1016/S0140-6736(14)61595-6.

71 Banerjee S. Multimorbidity–older adults need health care that can count past one. *Lancet* 2014; published online Nov 6. http://dx.doi.org/10.1016/S0140-6736(14)61596-8.

72 Steptoe A, Deaton A, Stone AA. Subjective wellbeing, health, and ageing. *Lancet* 2014; published online Nov 6. http://dx.doi.org/10.1016/S0140-6736(13)61489-0.

73 Bloom DE, Chatterji S, Kowal P, et al. Macroeconomic implications of population ageing and selected policy responses. *Lancet* 2014; published online Nov 6. http://dx.doi.org/10.1016/S0140-6736(14)61464-1.