Review Article

Compression and Expansion of Morbidity

Secular Trends Among Cohorts of the Same Age

Siegfried Geyer, Sveja Eberhard

Summary

Background: Morbidity is said to be compressed when the interval from the onset of a disease or disability to death becomes shorter over time, or when the incidence of the disease or disability declines over time. In the reverse situation, morbidity is said to be expanded.

Methods: This review is based on national and international studies retrieved by a selective literature search on secular trends in morbidity and mortality. The findings were derived from data from surveys and registries, and from the routine data of health insurance carriers.

Results: Three different types of secular trends in morbidity were seen. For some diseases (e.g., lung cancer, stroke, and dementia), morbidity among the elderly was compressed over time. On the other hand, for multimorbidity and type 2 diabetes including comorbidities, morbidity expanded over time. Unexpectedly, a double development was seen in certain other conditions, with both compression among the elderly and expansion among the middle-aged: this was particularly so for myocardial infarction, grip strength, and indicators of general health.

Conclusion: The notion of morbidity being reduced by compression seems less tenable in view of the double development just mentioned. The findings suggest that the observed secular trend toward better health among the elderly has not persisted among the more recently born cohorts. This can have negative effects on social security systems, particularly with respect to retirement ages being deferred or made more flexible, as well as the cost of health care.

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Medical Sociology Unit, Hannover Medical School, Hannover: Prof. Dr. Siegfried Geyer
AOK Niedersachsen, Hannover: Dr. Sveja Eberhard

Demographic change entails an increase in the proportion of older people in the total population while life expectancy is increasing (1). For the healthcare and social security systems this presents challenges, especially in view of healthcare costs, which rise with increasing life age, working lifetime, changes to retirement age, and funding of old age pensions. A key question concerns shifts in the range of diseases—that is, whether with increasing life expectancy the number and severity of diseases increase and whether the manifestation of disease and disabilities shift to older age groups. We are about to show that this is only partly the case.

In acute medicine, increased treatment needs will arise as a result of overweight/obesity and in type 2 diabetes, especially with regard to comorbidities. The rise in multimorbidity will require more resources for the treatment of a small number of severe, non-fatal disorders. These shifts occur primarily in middle age, and in outpatient care, occupational and non-occupational prevention in the area of nutrition and exercise are therefore of substantial importance.

In the early 1980s, James Fries formulated the hypothesis of morbidity compression as a positive development in morbidity development. It predicts that as a result of primary prevention, healthier lifestyles, and improved living conditions disease rates will fall and a shift in age will occur in the development of disease and disability into later life phases (2, 3) (*Box 1*). The described development is population based and incidence based—it does not allow for assumptions about the duration of diseases. Fries considered as early as the 1980s that on this background it might become possible to raise the retirement age (4). By contrast, Gruenberg's hypothesis of morbidity expansion (*Box 1*) postulates on the background of continually improving medical treatment options an increase in the number of people with chronic diseases and longer periods spent in a state of disease and disability (5).

The expansion hypothesis relates primarily to chronic diseases that cannot be cured and in which primary treatment is often associated with further impairments that require treatment. Morbidity expansion can also increase as a result of successful screening measures and improved diagnostics. Both hypotheses are often discussed as contradicting each other but they are not mutually exclusive. On this background the question arises as to which trends population-based health follows in the overall

perspective and which consequences result from this for outpatient and inpatient care.

We present an overview of the results regarding morbidity expansion and compression to date. So far, we can differentiate three development directions—that of compression, expansion, and a combination of compression plus expansion in the same disorders. In all cases, social differences are present in disease risks (6).

The results were selected on the basis of published studies and are additionally based on a selective literature search in PubMed with the search terms "morbidity compression", morbidity expansion", "morbidity", "mortality", "longitudinal study", and "cohort study" in titles and abstracts, without restrictions on the date of publication. We included only original articles. In the Medical Subject Headings (MeSH) on the US Library of Medicine, the terms "morbidity compression" and "morbidity expansion were not found. In parallel we carried out a Google search for the relevant German terms. Finally, we included specific long term studies on the basis of expert recommendations. Our search yielded three types of original articles that are documented in table form:

- Very few studies have been published on morbidity compression and expansion because the simultaneous investigation of morbidity and mortality is only rarely feasible on the basis of the available data (*Table*).
- Studies of morbidity trends over longer time periods are also small in number, and if they do exist they relate to a limited number of diseases (*eTable*).
- Longitudinal studies are mostly prediction studies considering a starting population of limited size, on the basis of which compression and expansion can, however, not be studied because dropouts are not substituted. Furthermore they encompass different groups of persons whose findings cannot be generalized to the general population (*eTable*).

BOX 1

Morbidity compression and expansion

In morbidity compression, in the first variant the mean age at which illness and disability occur shifts into later life phases. The second variant of morbidity compression consists of a reduction in morbidity over time—that is, fewer people get ill. This may take place on the background of constant as well as increasing life expectancy or a rising mean age at death. In either scenario, the healthy period of life is extended. Morbidity compression develops as a result of improved primary prevention, improved material living conditions, and a clean environment.

Morbidity expansion entails a shift of the mean life age at which disease or disability occur over time to a younger age. As a result of medical progress, more and more people survive severe illness and survive for longer periods, but at the price of impaired health and long-term need for treatment. As a result the proportion of sick and health-impaired persons among the total population rises over time.

Morbidity compression

In high-income countries, all kinds of cardiovascular disorders decreased over time, and their occurrence shifted into older age groups (7). For stroke, a Swedish study described similar results (8). The Framingham Study from the US reported that between 1962 and 2005 the 10-year risk for stroke in over-55-year-olds decreased from 11.7% to 10.6% (9).

Lung cancer is a behavior-dependent disease because of its association with smoking. In parallel to the decrease in nicotine consumption, a reduction can be expected with a time lag (10, 11). The trend in men points to fall in incidence rates; in women, differences were seen depending on the study design, according to age and social status. For the time period 2006–2017, the mean age for the occurrence of lung cancer standardized by the size of the age groups in men was 68.4 (standard deviation [SD]: 10.3) years, in women it was 67.8 (11.7) years. For the time period under study, incidence rates in men fell by 31%; standardized mortality rates fell to the same extent (12). For women, lung cancer rates also fell over time. For both sexes the results can be explained with a reduction in nicotine consumption. For this disease, a morbidity compression has therefore taken place (12).

The incidence of stroke also fell in 2006–2016—a total of 42 966 cases were registered for 5 079 764 person years. When differentiated by subgroups the incidence varied according to sex and social status. Overall the described trends can be described as morbidity compression (13).

For the prevalence of dementias in 2006–2010 (502 065 person years and 10,881 cases of dementia) a routine data study showed that rates in women aged 75–84 fell by 1–2%. Expressed in lifetimes, for 65-year-olds the remaining lifetime without dementia in men rose by 1.4 months every year and in women, by 1.1 (14). These results reported on the basis of data from Germany were confirmed by findings from the Framingham Study in the US. Between 1986 and 2008 the age at which dementia was diagnosed increased by a mean of two years. The age of death simultaneously increased by about one year—this means that the lifetime spent with dementia fell from six years to three years (15).

Health improvements in Germany were also seen for the increase in the rates of 50–70 year old men and women who rated their health as "good" or "very good" in 1995–2015. This improvement can at least in part be attributed to an increase in physical activity, which is consistent with Fries's compression hypothesis. Self-rated health is an often used and valid indicator for general health (16).

TABLE

Studien of morbidity compression with the covered time periods: incidence and/or age at onset and death

Study	Case numbers	Study period	Disorders	Longitudinal or cross sectional study	Result
Framingham Study, USA (15)	Initial N = 5205; of which case-control study with 317 dementia cases and 317 controls	Comparison 1977–1984 and 2004–2008	Age at onset of dementia	Longitudinal; comparison of two time periods	The age at diagnosis of dementia increased from the first to the second study period, illness duration reduced over time (morbidity compression).
"Morbidity compression and its alternatives" (Hannover) (12)	Routine data of the Statutory Sickness Fund for Lower Saxony (AOKN) with > 3 million members, as well as survey data sets	AOKN: 2005–2020; survey data: 2002–2018	Myocardial infarction, stroke, carcinoma of the bronchus, type 2 diabetes, grip strength, frailty, multimorbidity	Longitudinal; comparison of the same age groups by annual cohorts	**Morbidity expansion:** multimorbidity (21, e22), type 2 diabetes (20); **Morbidity compression:** carcinoma of the bronchus (e1); functional impairments (e2) **Compression at older age, expansion in younger age groups:** mycardial infarction (e3), grip strength (e4); depressive symptoms (e5)

Morbidity expansion

According to the latest diabetes report (17), type 2 diabetes is one of the most common diseases in the adult population, with a prevalence rate of 9%. The previously high estimated number of unknown cases has fallen considerably and is estimated to be 2.9% in men and 1.2% in women (18). Overall the diabetes report assumes an increasing rate in the population over time. A study including German routine data showed that in 2007–2919 prevalence rates had increased in all age groups (25^{th}–84^{th} year of life). Incidence rates also rose between the 25^{th} and 64^{th} year (19). Morbidity increases in young adults are a cause for concern because they are associated with a prolonged duration of illness and higher risks for comorbidities. Further studies therefore investigated trends in diabetes associated diseases over time (20). Between 2005 and 2017, comorbidities increased in men and women with type 2 diabetes. The findings were dichotomized because when all comorbidities were considered, increases were seen in all age groups for the less serious comorbidities, especially in the age group or 18–45-year-olds. For the severe comorbidities stroke or myocardial infarction, rates fell in all age groups, especially in those older than 65.

The findings are based on routine data and relate to diagnosed comorbidities. Impairments that did not reach the threshold for a diagnosis or which were not reported in a consultation with the doctor were not investigated. This gap constitutes a limitation to the validity of routine data, which can be filled by using—for example—data from the European Survey of Health, Ageing and Retirement in Europe (SHARE). SHARE includes men and women aged 50 or older. For 2004 and 2015 the rate of patients with type 2 diabetes who experienced functional impairments rose from 11.3% to 19.1% over the study period (18).

For multimorbidity, analyses using routine data from a statutory sickness fund showed that over 2005–2013, the years under study, this increased independently of the definition in men and women and across the age groups under study (see the *eBox* for the definition of multimorbidity). Further studies of statutory sickness fund data from 2005–2014 showed that life years spent with multimorbidity increased by 2.7 years in men and by 3/2 years on women. The lifetime with multimorbidity increased more than the life expectancy (21). This means that a notable expansion exists. As for specific diseases, multimorbidity is also subject to socially unequal distributions following well-known patterns (22).

Compression and expansion as simultaneous developments

According to the heart report 2019, the hospital admission rate after acute myocardial infarction in men was 347.8 per 100 000 population in 2018. For women, it was 165.9/100 000 (23). Since most of the morbidities occur after the 65^{th} year of life, myocardial infarction is primarily a phenomenon of older life age. An analysis over the entire lifespan showed for 2006–2017 a notable fall in incidence rates in men. These also fell in women, but to a less pronounced degree. In men the adjusted age for occurrence per year rose by about 1.3 months, while age at death rose slightly less pronouncedly. On the background of a notably older age at occurrence of a myocardial infarction in women (75.7 years; and 66.2 years in men), no further increase was observed in women (12). When looking separately at the age groups above the 70^{th} and below the 50^{th} years of life, a compression was seen in the older age group whereas the age on occurrence in the younger age fell—this means an expansion took place (24). This dual trend was surprising from the perspective of the compression hypothesis, but is highly credible because it was found on the basis of two differently compiled data sets.

For 2002–2016, an international comparison showed that in the German sample, everyday health

impairments were less common in the cohorts born in 1940–1970 than in those born earlier or later (25). Relevant analyses were carried out for grip strength as an indicator for general health for Germany, Sweden, and Spain. The data came from the surveys of the SHARE Study 2004, 2007, and 2013. The analyses also showed a dual trend by age cohort. An increase in grip strength was seen in people older than 80—which is consistent with Fries's compression hypothesis—a stagnation or even decrease in the trend was seen for those born after 1960 (26). Findings of the time trend of subjective health point in the same direction. Improvements occurred particularly after people entered retirement whereas the positive trend in late career subjects and in younger adults were notable weaker (27).

This dichotomous trend has rarely been discussed in the international literature. For the USA, however, data are available that show that on the background of life expectancy that has been falling since 2015, mortality rates in age groups in gainful employment have risen in recent years (28). In the USA, a substantial morbidity expansion has thus taken place. The causes include the consequences of rising obesity rates, the opioid crisis, drug misuse, suicide, and changes in working conditions. These explanations can, however, be generalized to German only to a limited extent.

Conclusions

Studies of morbidity compression were linked to the expectation that diseases and disabilities decrease in the population over time. International studies as well as studies from Germany showed that compression has taken place in older age groups. In parallel, medical progress has increased the number of diseases that can be cured and improved the survival chances of patients with chronic diseases (29, 30), which can be interpreted as morbidity expansion. These trends may give rise to optimism, but they are simultaneously undermined by the dichotomous trend of compression at older ages and simultaneous expansion in the economically active age groups. Increasing morbidity in the actively working population therefore occurs jointly with a shrinking younger, professionally active population.

Morbidity compression from a health political perspective opens up opportunities for raising the statutory retirement age. This should be done in dependence of the morbidity status of defined professional or otherwise defined social groups (31) and enable introducing flexibility into people's retirement age in practice.

The Robert Koch-Institute modeled the trend in healthcare costs under the conditions of the compression and expansion hypotheses. While under conditions of expansion healthcare costs were assumed to rise depending on age but also age-independently, morbidity compression should be associated with a flattening rise in healthcare costs and a shift of costs into older age groups (32).

BOX 2

Consequences

From a health political perspective, delaying the statutory retirement age for the baby boomer generation seems justified, since especially in cardiovascular disorders and malignancies, morbidity compression has taken place. For the following birth cohorts, introducing a flexible retirement age seems sensible from a sociopolitical perspective.

Driven by the increase in sedentary jobs and the consumption of highly calorific food, cardiovascular disorders and malignancies are increasing in economically active people in subsequent birth cohorts.

In inpatient and outpatient settings an increase in obesity-associated disorders is to be expected.

In view of the long-term increase in sedentary jobs and rising rates of people with overweight and obesity, it will be difficult to identify specific target groups for preventive, exercise based interventions. At the population level a dietary recommendation can be made to introduce easy to understand labeling, raise prices for foods containing fat and sugar, and improve people's knowledge and awareness about nutrition from kindergarten age to adulthood.

Sedentary activities are increasing in all areas of life; for this reason, exercise and physical activity programs in children's day centers and schools should become a crucial component of the care services/activities. In companies, interruptions to sedentary occupations should become part of occupational prevention.

The question remains unanswered how long the time period will last until a morbidity expansion takes place for other diseases too, which raises questions regarding the extent to which this trend can be influenced (or not). Especially the development of type 2 diabetes in younger age groups will in curative medicine be associated with an increase in the number of cases to be treated, more intense patient education/training, and increased cardiopreventive medications (33).

In the lead-up to disease, the structure of gainful employment has once again become the focus of attention in recent years. To date, risks posed by physical burdens, exposure to noxious substances, and chronic stress have been considered, such as occur in blue-collar workers or craftspeople/tradespeople. In recent years, health risks have taken center stage that rise from an increase in the number of jobs that are carried out mainly in a sedentary position or that did not entail so much sitting down in the past (34, 35).

The health effects manifesting as overweight, type 2 diabetes, and cardiovascular disorders are a growing problem for the health of populations. Studies from

the USA have pointed out the parallel trend of a decrease in physical activity and a simultaneous increase in calorie intake (36). This highlights a need to reduce passive forms of leisure time activity (37) and to introduce proportional preventive measures in the workplace. Structurally, these are the side effects of technologies that on the one hand help avoid severe physical burdens and simplify working processes, but on the other hand reduce opportunities for physical activity to the extent that they entail novel health risks (36, 38). For the purposes of prevention it is recommended to spend less than half the day sitting down, get up regularly, and work fewer than five hours per day in a sedentary position (34). Occupational preventive measures that anchor these recommendations structurally, should notably improve their effectiveness at the staff level (*Box 2*).

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Contributors
Dr. phil. Johannes Beller, Dr. Jelena Epping, MPH Batoul Safieddine, PD Dr. Stefanie Sperlich, Dr. Juliane Tetzlaff, M.Sc. und Fabian Tetzlaff, Medizinische Soziologie, Medizinische Hochschule Hannover; Robert Koch-Institut, Berlin

Dr. Jona Stahmeyer, AOK Niedersachsen, Hannover

Conflict of interest statement
The authors and contributors declare that no conflict of interest exists.

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Corresponding author
Prof. Dr. Siegfried Geyer
Medizinische Soziologie
Medizinische Hochschule Hannover
Carl-Neuberg-Str. 1, 30625 Hannover, Germany
geyer.siegfried@mh-hannover.de

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► **Supplementary material**

eReferences, eTables, eBox:
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eTABLE

Longitudinal studies of morbidity trends with the time periods covered and summarized results*

Study	Number of cases	Study period	Disorder	Longitudinal or cross sectional study	Result
Population based registry study of stroke incidence (France) (e6)*	Population based stroke registry of the city of Dijon; basis: population of the city (152 606 people)	1985–1999 and 2000–2006	Stroke	Longitudinal; comparison of two time periods	The age at the first stroke increased in men from 66 years in 1985 to 71.7 years in 2006. In women the age increased from 67.8 to 75.7 years.
Population based study (Sweden) (8)	Population registry of Sweden; 121 496 myocardial infarctions, 61 421 strokes	1987–2010	Stroke, myocardial infarction	Comparison of morbidity rates over time	In men, incidence rates of myocardial infarction and stroke fell over time, whereas they remained stable in women.
Greater Cincinnati/ Northern Kentucky Stroke Study (GCNKSS), USA (e7)	Number of registered strokes: 1993/94: 1942; 1999: 2 034; 2005: 1916	1993/94; 1999 and 2005	Stroke	Retrospective, population based study of incidence and mortality	Over time the mean age in stroke decreased from 71.2 to 69.7 years. The stroke rate among those younger than 55 rose from 12.9 % to 18.6 %..
National Inpatient Sample (NIS) as part of the Healthcare Cost and Utilization Project (e8)*	Hospital admission rates in the age groups 18–64 years	1995–2012	Stroke	Registry study	Hospital admission rates for stroke in the age groups younger than 55 doubled over the study period.
Framingham Study, USA (e9)	Age group 35–54 years: N = 10 348 Age group 55–103 years: N = 11 494	Period 1: 1962–67/ 2: 1971–76/ 3: 1987–91/ 4: 1998–2005	Stroke in two age groups (35–54 and 55–103 years)	Longitudinal; comparison of four time periods	The mean 10 year stroke rates in the older age groups fell from 11.7 % to 10.6 %, and in the younger group from 2.4 % to 1.7 %..
Nurses Health Study I, II, and III, USA (e10)	Married nurses aged 25 to 55 years in several US states, from 2015 men were also included	Study I: 1976+ Study II: 1996/2004+ Study III: 2010+	Originally contraceptive-associated symptoms, later expanded to include disease in general	Prospective studies of prediction of morbidities that are associated with health-relevant behavior	No analyses of morbidity compression or expansion were carried out.
Minnesota Nun Study, USA (e11, e12)	678 Catholic nuns at the initial age of 75–102 years	Recruitment between 1991 and 1993	Alzheimer's dementia	Longitudinal study of healthy ageing: effects of education and lifestyles for predicting the risk of developing Alzheimer's disease	No analyses of morbidity compression or expansion were carried out.
British doctors study, United Kingdom (e13)	Initially 34 439 male British doctors	Start in 1951 with regular follow-up surveys over > 50 years, final data collection in 2001	Prediction studies of health consequences of smoking and nicotine associated mortality	Longitudinal (panel) study with repeated surveys of the original cohort for predicting morbidities at two-year intervals	No analyses of morbidity compression or expansion were carried out.
Health Professionals Follow-Up Study, USA (e14)	Initially 51 529 men in various healthcare professions	Start in 1986, final follow-up survey in 2020	Prediction studies of cancer, cardiac, and vascular disorders as well as mortality	Longitudinal (panel) study with repeated surveys regarding the association of diet/nutrition and chronic disorders	No analyses of morbidity compression or expansion were carried out.
INTERHEART Study (e15)	N = 29 972 participants from 52 countries	Study period 1999–2003	Prediction of myocardial infarction and other common disorders as well as prevention by reducing risk factors	Case-control study; male and female patients after a myocardial infarction were compared with controls	No analyses of morbidity compression or expansion were carried out.

* Studies e6 und e8 consider the long-term mortality trend, studies (e7–e15) are longitudinal studies of predicted health related endpoints.

eBOX

Definition of multimorbidity

Multimorbidity is the term used to describe the concomitant presence of several diseases in a person. The World Health Organization (e15, e16) suggested as a definition the presence of three and more diagnoses. If the aim is to study multimorbidity into very old age this definition is not helpful because from a certain age 80–100% of the population would have to be categorized as multimorbid. No differentiation by degree of multimorbidity has been done (e17). In practice, we need to differentiate between comorbidity indices (for example, the Elixhauser or Charlson index), which predict an endpoint (for example, mortality, inpatient admission) based on the main diagnosis (e18). By contrast, multimorbidity indices are to be seen as descriptive. The demarcation to comorbidity indices is flexible, however, because prediction analyses can be carried out with multimorbidity measures too, such as the Cambridge multimorbidity score (e19) or the definition from the MULTICARE Study (e20). All concepts of multimorbidity or comorbidity have in common that the validity of included diagnoses can be stated only in view of defined endpoints. Without endpoints it amounts to counting diagnoses to describe morbidity in specific target groups or the total population.

Our studies dealt descriptively with the trend in (multi-)morbidity over time in a population and was based on the diagnoses included in the MULTICARE Study (e20). In addition to the diagnoses, the factor time also had to be included. When using routine data, the practice of making an increasing number of increasingly differentiated diagnoses has to be considered. In our data, multimorbidity rates rose implausibly from one calendar year to the next. So as to be able to differentiate with life age increasing, we set a higher threshold for multimorbidity studies, the final stage as a combination of at least six diagnoses with associated prescription of at least five active pharmaceutical ingredients in at least two quarters of a given year (e21). In each of these definitions, the rate of men and women with multimorbidity rose over the calendar years even in the last-named and most restrictive variant

Questions on the article in issue 4/2022

Morbidity compression and expansion

cme plus

The submission deadline is 24 November 2023. Only one answer is possible per question.
Please select the answer that is most appropriate.

Question 1

When was the morbidity compression hypothesis first postulated?

a) In the early 1960s
b) In the early 1970s
c) In the early 1980s
d) In the early 1990s
e) In the early 2000s

Question 2

Who formulated the morbidity compression hypothesis?

a) Ernest Grünberg
b) Kate Lorig
c) Marshal Folstein
d) Francis Crick
e) James Fries

Question 3

Which is the first variant of morbidity compression described in the article?

a) An increase in age standardized mortality over time
b) Longer as a result of improved treatment options
c) Lower average life expectancy
d) A shift of the mean age of disease onset into later life phases
e) Eradication of chronic infectious diseases

Question 4

For which disorder did the Framingham Study show morbidity compression?

a) Age at dementia diagnosis
b) Parkinson's disease
c) Type 2 diabetes mellitus
d) Crohn's disease
e) Multiple sclerosis

Question 5

For which disorder did the rate of patients with functional impairment according to the Survey of Health, Ageing and Retirement in Europe (SHARE) rise between 2004 and 2015 from 11.3 % auf 19.1 %?

a) Multiple sclerosis
b) Rheumatoid arthritis
c) Hypertension
d) Type 2 diabetes
e) Crohn's disease

Question 6

For which comorbidities of type 2 diabetes does the article report a reduction of the rate across all age groups between 2005 and 2017?

a) Insomnia and retinopathy
b) Depression and hypertension
c) Stroke and myocardial infarction
d) Neuropathy and renal failure
e) Retinopathy and neuropathy

Question 7

For which disorders did survey data (2002–2018) and routine date from the Statutory sickness fund for lower Saxony (2005–2020) show show a morbitity expansion?

a) Carcinoma of the bronchus
b) Type 2 diabetes
c) Colon cancer
d) Melanomas
e) Stroke

Question 8

Which birth years in a German sample in 2002–2016 were found to have fewer everyday impairments than in those born earlier or later?

a) 1920–1945
b) 1930–1950
c) 1940–1970
d) 1970–1990
e) 1980–1995

Question 9

Since which year has life expectancy been found to fall in the USA?

a) 1990
b) 2000
c) 2011
d) 2015
e) 2020

Question 10

Which comparison between the sexes is true for myocardial infarction?

a) Incidence rates in men and women are identical, but women tend to have heart attacks at a younger age.
b) The incidence in men is lower, but their average age at disease onset is older than for women.
c) The rate of myocardial infarction in men is higher, and their mean age at disease onset is younger than in women.
d) Women are affected less commonly than men, and their mean age at disease onset is younger than in men. .
e) Incidence rates in men and women are identical, but men more commonly have a heart attack at a younger age.