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ORIGINAL ARTICLE

Expansion or compression of multimorbidity? 10-year development of life years spent in multimorbidity based on health insurance claims data of Lower Saxony, Germany

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Abstract
Objectives Our study examined how life years spent in multimorbidity changed over a period of 10 years (2005–2014) and whether morbidity expansion or compression has taken place. There is a little evidence on whether life years gained due to increasing life expectancy are spent in good health, or if they are accompanied by morbidity expansion.
Methods The analyses are based on German administrative claims data. Multimorbidity was defined as a combination of at least six chronic conditions and polypharmacy. After having estimated age-standardized prevalence, time trends for life years with and without multimorbidity, and the proportion of life years spent in multimorbidity (morbidity ratio) were estimated.
Results Prevalence proportions of multimorbidity rose continuously. Increasing life expectancies were accompanied by increasing life years with multimorbidity, decreasing multimorbidity-free life years, and by an increasing morbidity ratio.
Conclusions The lifespan spent in multimorbidity was increasing over time. Our findings indicate a growing burden of multimorbidity and an increasing proportion of life years with multiple chronic conditions. It can be concluded that an expansion of morbidity in absolute and in relative terms has occurred. The findings stress the importance of prevention, healthy lifestyles, and improved medical care strategies meeting the specific requirements of patients with multimorbidity.

Keywords Multimorbidity · Time trend · Prevalence · Compression · Expansion

Introduction

Chronic conditions have a large share of the morbidity burden of populations (WHO 2014). Rising life expectancy leads to an increasing number of people reaching a high or very high age. A health-related consequence of this development is a rising burden of chronic conditions (Meslé and Vallin 2006). In the elderly, multimorbidity has become rather the rule than the exception (Harrison et al. 2014; Violan et al. 2014; Sinnige et al. 2013).

If life years are gained, it has to be examined whether this additional time is spent in good health or whether extended periods of morbidity are to be expected. Three concepts describe the development of morbidity: According to Fries, compression of morbidity occurs if the onset of chronic illness and disability are postponed towards the end of life (Fries 1980). Healthy life years will be gained, and the active period will be extended. Fries assumed that improved primary prevention and improved living conditions are pushing these developments. His studies on runners (Fries 2012) and on alumni (Chakravarty et al. 2012) support his hypothesis. In contrast, Gruenberg (Gruenberg 1977) put up the hypothesis that morbidity expansion may occur. Improved medical care will reduce lethality after the occurrence of complications. Survival will be prolonged in spite of chronic

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diseases being present. Manton formulated another hypothesis how morbidity might develop over time: the dynamic equilibrium (Manton 1982). He assumed that even if life expectancy is increasing, the relative proportion of life years spent in morbidity may remain unchanged. In contrast to Gruenberg's hypothesis, medical progress will lead to improved quality of life, lower degrees of disability, and lower impairments of everyday activities.

Studies on morbidity compression conducted so far have produced conflicting evidence. The findings are dependent on the health measures used, on the database, and on the population under study. The majority of studies were based on surveys and focused on self-reported functional limitations, and most findings are in favour of morbidity compression and on the dynamic equilibrium (Robine and Jagger 2005; Crimmins and Beltrán-Sánchez 2011; Trachte et al. 2015; Freedman et al. 2016; Jeune et al. 2015; Lagergren et al. 2016). Studying specific diseases rather than general health impairments may allow a deeper insight in morbidity shifts over time (Geyer 2016). Multimorbidity has rarely been considered, but the few available studies indicate a rising burden of multimorbidity (Uijen and van de Lisdonk 2008; Dhalwani et al. 2016; van Oostrom et al. 2016). Multimorbidity is an important issue, because it can be expected to precede more severe health conditions or it may accompany them.

With our own study, we wanted to go a step into this direction by examining the development of a broad range of chronic conditions in the elderly. The study is based on administrative claims data from a large German health insurance, and an observation period of 10 years will be covered. The following research questions will be addressed:

1. Has the number of expected life years with multimorbidity increased over time?

   An absolute expansion occurs if the number of life years spent in multimorbidity is increasing.
2. Has the number of expected life years without multimorbidity increased over time?
   If life expectancy is increasing, this must not necessarily be accompanied by an increase in multimorbidity-free life years.
3. Has the proportion of life years with multimorbidity relative to total life years (morbidity ratio) changed over time?
   This question is addressing the development of multimorbidity in relative terms. If the number of life years with and without multimorbidity is expanding accordingly, a dynamic equilibrium occurs.

Methods

The analyses are based on claims data of a German health insurance located in Lower Saxony, the AOK Niedersachsen (AOKN). About 10% of the German population live in this federal state. The data were collected for accounting purposes and cover approximately one-third of the population of Lower Saxony. The statutory health insurances of Germany are part of a welfare state-based health care system based on insurance premiums. Medical care is provided at low or no additional payments. Approximately 90% of the German population (87% in 2005 and 85% in 2014) (Bundesministerium für Gesundheit 2009, 2015) has health care coverage by this system.

The data contain demographic and socio-economic information, in- and outpatient diagnoses, medications, and mortality information. All the information is dated, thus making it possible to depict the chronological order of events. The health insurance population is comparable with the total population of Lower Saxony as well as of Germany in terms of the distribution of age and sex. However, individuals with lower occupational positions are over-represented (Jaunzeme et al. 2013). With the studies on health inequalities in mind, it can be assumed that morbidity rates should be higher than in the total population.

The following analyses are based on the years 2005 to 2014 as observation period. Data of all individuals of 60 years and older are used to cover the age groups where chronic conditions are frequent and where multimorbidity is common (Harrison et al. 2014; Violan et al. 2014; Sinnige et al. 2013). Insured were included without restrictions of the length of insurance period during the year of observation, but most of them were insured over the entire year. Shorter insurance periods may arise mainly from death (Table 1). As our data set represents the complete insurance population of the AOKN aged 60 years and older, many individuals are included over several years. The data set contains a higher proportion of women (4,226,303 cases, 60%) than of men (2,835,142 cases, 40%) (Table 1).

Definition of multimorbidity

Up to now, there are hardly any studies on how to measure time trends of multimorbidity. Multimorbidity is usually defined as the presence of two or more chronic conditions in the same individual (van den Akker et al. 1996). If this definition is applied to our data, very high prevalence proportions emerge leading to a ceiling effect, thus making it impossible to differentiate between individuals with and without multimorbidity and to depict further developments. Some authors also maintained that increases of morbidity as measured by medical diagnoses may not only be caused by deteriorations of health, but also by higher sensibility of

Table 1 Characteristics of the study population (Lower Saxony, Germany, 2005–2014)

	Men		Women	
	N	%	*N*	%
Year				
2005	269,092	9.5	431,133	10.2
2006	266,755	9.4	422,819	10.0
2007	265,740	9.4	416,140	9.8
2008	264,240	9.3	409,269	9.7
2009	264,359	9.3	404,102	9.6
2010	299,038	10.5	435,158	10.3
2011	300,689	10.6	432,426	10.2
2012	301,856	10.6	429,197	10.2
2013	301,631	10.6	424,894	10.1
2014	301,742	10.6	421,165	10.0
Age group				
60–64	621,307	21.9	643,181	15.2
65–69	617,310	21.8	708,962	16.8
70–74	636,655	22.5	834,496	19.7
75–79	483,519	17.1	765,346	18.1
80–84	290,770	10.3	620,396	14.7
85–89	133,692	4.7	412,306	9.8
90+	51,889	1.8	241,616	5.7
Deaths per year and age-standardized mortality rate[a]				
2005	12,238	5.0	18,379	4.6
2006	12,236	5.0	17,601	4.4
2007	12,082	4.8	17,422	4.4
2008	12,395	4.9	17,696	4.5
2009	12,361	4.8	17,507	4.5
2010	13,331	4.7	18,304	4.4
2011	13,625	4.6	17,825	4.2
2012	13,995	4.6	18,137	4.3
2013	14,453	4.7	18,639	4.4
2014	14,099	4.5	17,517	4.1
Insurance periods per year				
≥365 days	2,637,476	93.0	3,971,055	94.0
<365 days	197,666	7.0	255,248	6.0
Total	2,835,142	100.0	4,226,303	100.0

[a]Standard population insured individuals of the Allgemeine Ortskrankenkasse Niedersachsen (AOKN) 2009 (statutory health insurance, Lower Saxony, Germany)

physicians and patients (Uijen and van de Lisdonk 2008). This may increase accuracy and completeness of coded diagnoses and foster early detection of chronic diseases over time. For time-related analyses based on health insurance data, it is, therefore, appropriate to use a more robust measure than simple counts of coded diagnoses. Furthermore, the measure has to be sensitive to change to depict time trends in prevalence proportions and allow differentiating between multimorbid and non-multimorbid individuals up to the highest age groups. To tackle this issue, the previous analyses investigating time trends in multimorbidity based on different definitions were performed. These analyses led to the assumption that the more rigorous the definition of multimorbidity, the more robust the estimated time trends. This may occur, because less severe chronic conditions not in need of a complex medication are more likely to be diagnosed earlier and more frequent over time (Tetzlaff et al. 2016). Thus, multimorbidity was defined as the presence of six or more chronic conditions combined with polypharmacy. Polypharmacy as additional criterion shifts the focus to individuals requiring a higher degree of medical care and reduces the impact of inflated numbers of diagnoses that may arise out of changed coding practices. The choice of chronic conditions was based on 45 out of 46 diagnostic groups and risk factors as used in the MultiCare study (van den Bussche and Scherer 2011). This study was performed for assessing multimorbidity in primary care settings in Germany and for improving medical care of patients with multiple chronic conditions. The diseases and risk factors included are covering a broad range of chronic conditions among the elderly.

All diagnoses in our data set are coded according to ICD-10. In our study, hemorrhoids were excluded, because the ICD-10 code was changed during the study period. This led to a reduction of coded diagnoses. All other ICD-10 codes remained unchanged throughout the study period. In accordance with the previous studies, polypharmacy was defined as the prescription of at least five different drugs as coded according to the Anatomic Therapeutic Chemical Classification System (ATC) within a given year (WHO Collaborating Centre for Drug Statistics Methodology 2015). The drugs were differentiated at the fourth precision level to allow for changes within the same chemical subgroup. To exclude non-chronic conditions and short-term medications, only diagnoses and drugs were included that appeared in two or more quarters of a given year. An exception was allowed in individuals with insurance periods of less than 92 days per year.

Statistical analyses

To allow for a first insight in the development of multimorbidity over time, age-standardized prevalence proportions of the insured individuals aged 60 and older were estimated for each calendar year. To permit comparisons between years, age-standardized prevalence proportions are used. The age structure is kept constant over time using the age distributions of the insured women and men in 2009 as standard population. For these estimations, single-year age groups were used.

The Sullivan method (Sullivan 1971) was used for analysing the development of the average lifespan spent with and without multimorbidity. It permits to split the expected remaining life years by combining information on morbidity and mortality. Thus, the Sullivan method provides measures of health expectancies which allow comparing the morbidity burden of populations at different points in time. These measures are robust as long as the shifts in incidence rates are smooth and regular over time (Jagger et al. 2006), which is the case in our data set.

For these analyses, the total life expectancy of the population under study is needed. Life expectancy at age 60 is computed using period life tables (Chiang 1984) for women and men for the years 2005–2014. The estimates are based on case numbers between 12,082 (men 2007) and 18,639 (women 2013) deaths per year (Table 1).

To decide to what extent the remaining life years are accompanied by multimorbidity age-specific prevalence estimates is required (Sullivan 1971). They were derived from the insured individuals aged 60 and above by logistic regression models using standard error estimates that allow for repeated observations. The regression models are stratified for sex and include age (single-year age groups) as centred second-degree polynomial and calendar year. Age-specific probabilities of being multimorbid and standard errors fitted by the models were gained using postestimation commands. Observed and estimated prevalence values are provided in Online Resource 1. The estimated values fit the observed values well. The estimated prevalence values and standard errors were used as input for the Sullivan analysis.

The Sullivan analysis provides estimates of the expected number of life years with and without multimorbidity for each year of observation. The proportion of life years with multimorbidity to the total life expectancy (morbidity ratio) was used to analyse the development in relative terms. All analyses were performed separately for men and women using StataMP 13 (StataCorp. 2013) and R (R Team RC 2014).

Results

In 2005, total life expectancy at age 60 amounted to 19.18 years in men and to 24.03 years in women. Despite some fluctuations, life expectancy increased over the observation period. Compared with 2005, in 2014, life expectancy was 0.69 years higher in men and 0.63 years higher in women (Fig. 1a).

In 2005, 18.6% of men and 22.1% of women were suffering from multimorbidity. In both sexes, age-standardized multimorbidity prevalence proportions rose continuously by 13% points between 2005 and 2014. Women had a higher prevalence than men (Table 2). Further information on the development of age- and disease-specific prevalence proportions is provided as online supplement. Age-standardized prevalence proportions of the 45 chronic conditions by calendar year are listed in Online Resource 2; age-specific prevalence proportions of the chronic conditions in 2005 and 2014 are documented in Online Resource 3.

The expected average lifespan spent in multimorbidity increased during the observation period. Between 2005 and 2014, life years with multimorbidity rose by 2.7 years in men and 3.2 years in women. In 2014, men at age 60 could expect 6.1 and women 8.0 years of the remaining lifetime to be spent in multimorbidity (Fig. 1b).

Accompanied by increases in life years with multimorbidity, the remaining years expected to live without multimorbidity at age 60 decreased over time. Among men, the number of multimorbidity-free life years declined by more than 2 years to 13.8 years in 2014. Among women, this is even more pronounced. It amounts to 2.6 years during the observed period. With 16.4 years, women at age 60 have considerably more remaining multimorbidity-free years than men due to the higher total life expectancy (Fig. 1c).

The sharp increase in life years accompanied by multimorbidity along with the minor rise in life expectancy leads to a continuous growth of the proportion of life years spent in multimorbidity to the total life expectancy. This strong increase holds in a similar way for women as well as for men. Among men, the morbidity ratio rose from 17 to 31% and among women from 20 to 33% (Fig. 1d).

A detailed listing of total life expectancies, life years with and without multimorbidity, and the proportion of life years spent in multimorbidity at age 60, 70, and 80 including confidence intervals is documented in the online supplement (Online Resource 4). The time trends described above can be found in all age groups considered and the relative increase in the proportion of life years spent in multimorbidity remains similar throughout the age groups.

Discussion

The study has shown that the expected lifespan associated with multimorbidity has expanded over time. Comparing the increases in total life expectancy and the increases in the expected number if life years spent in multimorbidity, it can be concluded that the number of life years accompanied by multimorbidity rose at a faster pace than total life expectancy, pointing towards earlier onsets of chronic conditions. This leads to a relative shortening of multimorbidity-free life years. In sum, our findings indicate an expansion of multimorbidity in absolute as well as in relative terms. This applies to women as well as to men.

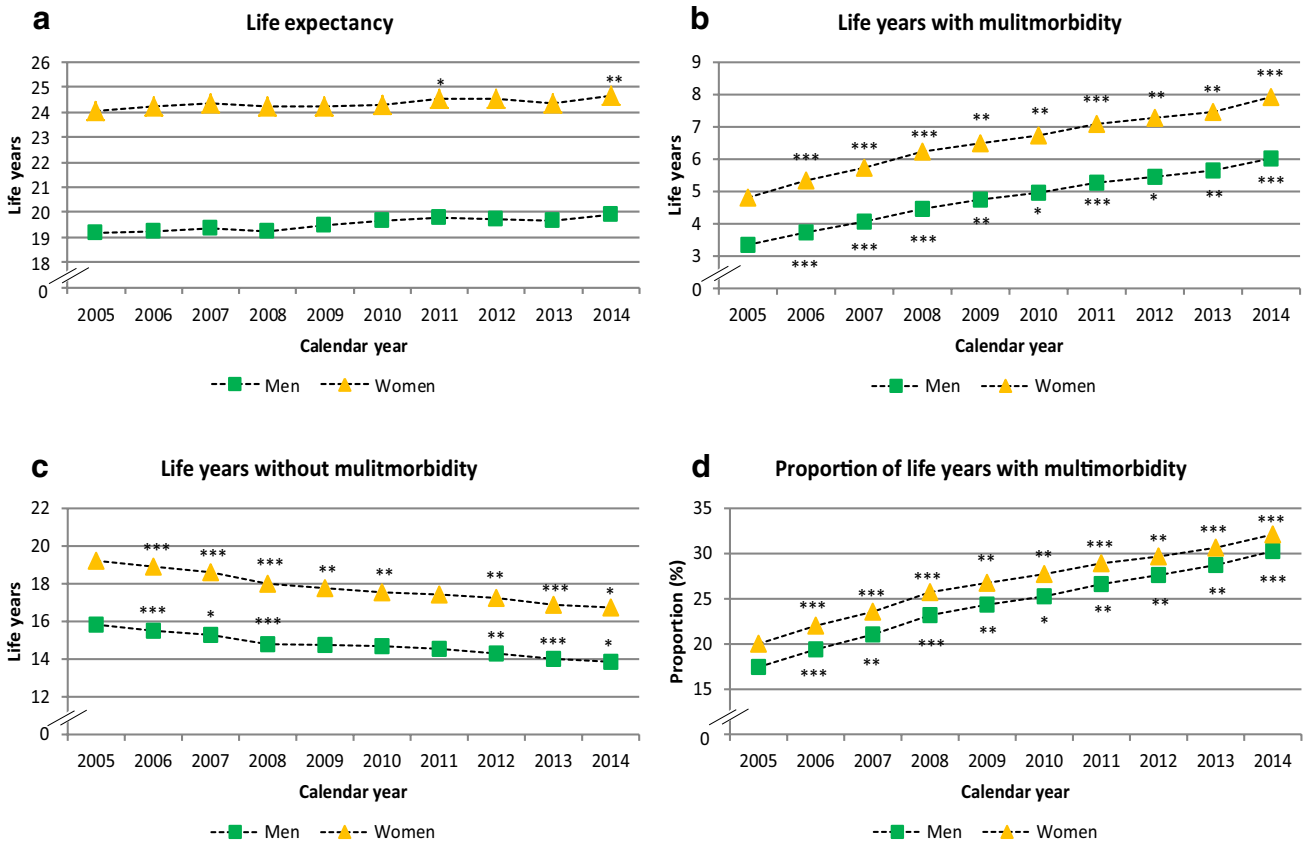

Fig. 1 Total life expectancy, life years with and without mutimorbidty, and proportion of life years with multimorbidity at age 60 by sex and calendar year (Lower Saxony, Germany, 2005–2014). *Significantly different from the previous year at 10% level; **significantly different from the previous year at 5% level; ***significantly different from the previous year at 1% level

Table 2 Age-standardized prevalence (%) of multimorbidity at age 60 and above by sex and calendar year (Lower Saxony, Germany, 2005–2014)

	Age-standardized prevalence (%)			
	Men	95% CI	Women	95% CI
2005	18.6	(18.4–18.7)	22.1	(22.0–22.2)
2006	20.6	(20.4–20.7)	24.2	(24.1–24.3)
2007	22.2	(22.1–22.4)	25.8	(25.7–25.9)
2008	24.1	(23.9–24.3)	27.7	(27.6–27.9)
2009	25.6	(25.4–25.8)	29.2	(29.0–29.3)
2010	27.1	(27.0–27.3)	30.7	(30.6–30.9)
2011	27.7	(27.5–27.8)	31.3	(31.1–31.4)
2012	28.7	(28.5–28.8)	32.1	(31.9–32.2)
2013	30.0	(29.8–30.1)	33.3	(33.1–33.4)
2014	31.6	(31.4–31.7)	35.0	(34.8–35.1)

Standard population insured individuals of the Allgemeine Ortskrankenkasse Niedersachsen (AOKN) 2009 (statutory health insurance, Lower Saxony, Germany)

In accordance with the previous studies (Uijen and van de Lisdonk 2008; Dhalwani et al. 2016; van Oostrom et al. 2016), we found rising prevalence proportions over time. In addition, the rates in women were higher than in men (Violan et al. 2014; Navickas et al. 2016). Women had a higher share of life years associated with multimorbidity, but the gender gap was narrowing over time as the morbidity ratio in men increased at a greater pace than in women. The emergence of morbidity expansion in terms of multimorbidity does not preclude that morbidity compression in other diseases does not occur. Decreasing risks of cardiovascular mortality and occurrence of severe cardiovascular diseases, especially in myocardial infarction and stroke, are well documented (Willis et al. 2013; Doblhammer et al. 2012; Meslé and Vallin 2006). Healthier lifestyles and improved medical treatment may lead to a decline of cardiovascular diseases which are causing high mortality. For Germany, decreasing proportions of smokers and physical inactive individuals have been reported (Robert Koch-Institut 2015) which may have contributed to cardiovascular health. However, the prolonged survival due to this development might result in a higher burden

of chronic conditions in the elderly. A next step in gaining more insight into the underlying processes contributing to the change in life years with and without multimorbidity should be a decomposition by kind of effect to identify what proportion of the change is due to changes in mortality and what proportion is due to changes in morbidity (Nusselder and Looman 2004).

Our findings are pointing towards morbidity expansion and are in line with a recent study that reported increasing proportions of life years spent in morbidity based on hospitalisation records (Walter et al. 2016). Following the assumption that multimorbidity usually precedes disability, our findings on expansion contradict earlier studies, where either morbidity compression or a dynamic equilibrium in terms of disability was reported (Robine and Jagger 2005; Crimmins and Beltrán-Sánchez 2011; Jeune et al. 2015; Trachte et al. 2015; Freedman et al. 2016; Lagergren et al. 2016). However, there is a little evidence how chronic diseases and disease clusters are associated with disabilities. Survey designs often lack specific information on how chronic conditions cumulate over the life course and how they foster impairments. Furthermore, the link between time trends in multimorbidity and time trends in disabilities needs further investigation. The impact of chronic conditions on the development of impairments of everyday functioning might lessen over time. If medical treatments are improving, there could be a chance of postponements of impairments to a later stage of disease trajectories.

Strengths and limitations

Our findings are based on large case numbers and on detailed information on diagnoses and medications. This makes it possible to include a wide variety of chronic conditions including less frequent ones. Multimorbidity measures based on a limited number of chronic conditions may lead to a selection of individuals with specific disease clusters and high degrees of multimorbidity (Ramond-Roquin et al. 2016). The information on diagnoses contained in our data set permit to depict a broad range of morbidity burden in the elderly. In addition, claims data have the advantage that findings remain unaffected by health-related non-response (Geyer and Jaunzeme 2014). This may occur in survey data where impaired health may lead respondents to refrain from participating. Morbidity levels of populations may then be underestimated (Rinne et al. 2015; Drivsholm et al. 2006).

A threshold of six diagnoses combined with polypharmacy should prevent the occurrence of ceiling effects with increasing age. This should also permit to differentiate in the highest age groups. Certain diseases might be detected earlier today and treated more vigorously in the health care system, which might lead to earlier and more frequent coded diagnoses over time. Therefore, the use of a multimorbidity measure based on simple counts of coded diagnoses might not be appropriate when studying time trends in multimorbidity based on health insurance data. Polypharmacy as an additional criterion shifts the focus to individuals requiring medication and medical observation. This combination of diagnoses and medication should also prevent changes of coding routines from having effects on the classification of multimorbidity. However, a clear distinction between increasing morbidity and shifts in physicians' prescribing behaviour over time cannot be made. Nevertheless, the previous analyses showed that the proportion of insured individuals treated with five or more drugs increased at a much slower pace than the proportion of individuals suffering from multimorbidity as defined on the basis of simple counts of coded diagnoses (Tetzlaff et al. 2016). Including another criterion for assessing the severity of multimorbidity, e.g., disability, could provide a deeper understanding of the link between coded multimorbidity and changes in limitations of daily activities over time but would require a linkage of health insurance data and survey data.

Almost all chronic conditions and all age groups contributed to the expansion due to rising prevalence over time (Online Resource 2, 3). The observed time trends in prevalence estimates are smooth and steady. Therefore, reforms are unlikely to be the driving force of the observed rise in multimorbidity.

It has to be noted that the life expectancy of our insurance population is lower than for the total population of Lower Saxony and for Germany. This is likely to be explained by their social structure. While the distributions of sex and age are similar to those of Lower Saxony, individuals holding lower occupational positions and with lower incomes are more frequent than in the total population (Jaunzeme et al. 2013). Furthermore, it has to be noted that the share of the German population not covered by statutory health insurances mainly consists of high earners or officials leading to an underrepresentation of high and very high income groups. As social inequalities are linked with inequalities in mortality (Valkonen 2006), this results in higher mortality and might explain the small gains in life expectancy over time.

Our study has shown that the expected average lifespan spent in multimorbidity was increasing over time, and the proportion of life years spent in multimorbidity have increased. Thus, an expansion of multimorbidity has taken place. The rising burden of multimorbidity stresses the importance to promote prevention and healthy lifestyles and underlines the significance to improve medical care strategies meeting the specific requirements of patients with multiple chronic conditions. However, whether this finding applies to all socio-economic groups or only to some

segments of the population needs further investigation. To explain the association between multiple chronic conditions and impairments, further work should investigate the links between multimorbidity, specific diseases, and disability with a focus on shifts in the impact of multimorbidity on impairments over time.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. The AOK Niedersachsen gave permission to use the data.

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