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# Myocardial infarction – frequency, trends and regional distribution in inpatient care in Germany. An analysis based on routine data from the statutory health insurance

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## Abstract

**Background:** As part of the German Burden of Disease Study, population-based measures of disease frequency are estimated. This allows regional patterns and temporal trends to be identified.

**Methods:** Rates of hospital-treated myocardial infarctions in the population were estimated cross-sectionally for the years 2017 to 2022 at the level of the spatial planning regions using routine data of persons insured in the statutory health insurance AOK, adjusted for age, sex and morbidity (administrative rate).

**Results:** In 2022, the rate was 270 myocardial infarctions per 100,000 people aged 25 years and over in Germany. The rate was higher in men (379) than in women (168). Myocardial infarction rates increased continuously with age. Between 2017 and 2022, age-standardised administrative myocardial infarction rates declined. The age-standardised regional distribution showed marked differences without a discernible geographical gradient.

**Conclusions:** The overall downward trend in hospital-treated myocardial infarctions in Germany is encouraging. Nevertheless, preventing myocardial infarction, and cardiovascular disease more broadly, remains one of the major public health policy challenges, particularly with regard to sex-related and regional differences.

**Keywords:** Myocardial infarction, Hospitalisation, Time trends, Morbidity, Risk factors, Age distribution, Health claims data, Secondary data analysis, Public health

This article is part of a series of articles with standardised analyses for the German Burden of Disease Study of the Robert Koch Institute.

## 1. Introduction

In order to support health policy decisions, the evaluation of the burden of disease in the population is of growing importance. Burden of disease indicators represent the 'loss' of life years at the level of population health caused by health impairments and premature death. The methods were originally developed by the Global Burden of Disease Study (GBD) [1–3].

Disease burden indicators make it possible to compare the impact of different diseases and to draw conclusions about regional differences and trends in population health over time. As part of the German Burden of Disease Study, this methodology is adapted and applied to diseases and injuries of high public health relevance [4, 5].

In order to calculate the morbidity-related burden of disease, epidemiological indicators of diseases and injuries are needed. These alone are of great value for public health research and fill existing information gaps for diseases for which comprehensive epidemiologic descriptions are rare or lacking.

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**Key messages**

- In 2022, the rate of hospital-treated myocardial infarctions in Germany was 270 per 100,000 people aged 25 years and over.
- The rate of hospital-treated myocardial infarctions was substantially higher in men than in women.
- Myocardial infarction rates increased with age.
- Across regions, age-standardised rates varied 2.3-fold, from 167 to 388 per 100,000 people.
- Between 2017 and 2022, rates of hospital-treated myocardial infarctions declined in both women and men.

Myocardial infarction is an important cause of the burden of disease in the population and is highly relevant to public health (Infobox). This article reports the national myocardial infarction rate as determined by the Robert Koch Institute's burden of disease study. Myocardial infarction registry data are not available nationwide in Germany and instead come from reference regions such as Augsburg [6], whose social structure, morbidity profile and health-care provision are not representative of Germany as a whole. For the present analysis, we therefore used nationwide inpatient case data and followed the German reporting standard for secondary data analyses [7].

**Infobox**
**Myocardial infarction**

Myocardial infarction (heart attack) is an acute medical emergency because part of the heart suddenly receives insufficient oxygen, which can cause permanent damage to heart muscle tissue [8–10]. Myocardial infarction is a potential acute complication of coronary heart disease (CHD, also referred to as ischaemic heart disease), which usually results from atherosclerosis (commonly described as 'hardening of the arteries'). Atherosclerotic changes can occur in any artery in the body and often affect the coronary arteries. Cholesterol accumulates in the vessel walls, causing inflammation and hardening and forming plaques that narrow the vessels from within [11]. If such plaques rupture, a blood clot (thrombus) can block the affected coronary arteries. A region of heart muscle then no longer receives sufficient oxygen and may subsequently die. The main risk factors for myocardial infarction include behavioural factors (tobacco use, physical inactivity, unhealthy diet), biological factors (unfavourable blood cholesterol or lipid profiles, high blood pressure, diabetes mellitus, overweight), psychosocial factors (chronic stress) and environmental factors (particulate matter) [12–14]. Studies of coronary heart disease have reported a pronounced socioeconomic gradient at both individual and regional level, which may partly reflect the unequal distribution of the various risk factors [15–18].

## 2. Methods

The present analysis is based on routine data of persons insured in the statutory health insurance (SHI) system. These data are mainly generated by cost accounting between service providers (e.g. hospitals) and payers (health insurance funds) in the health care system and are only subsequently made available for research purposes (secondary data analysis). Routine SHI data are collected continuously and allow trend analyses as well as small-area analyses. The data contain the most important information for estimating the disease frequency: (i) diagnoses according to the 10th revision of the International Statistical Classification of Diseases and Related Health Problems German Modification (ICD-10-GM), (ii) services according to the official classification for the coding of surgeries, procedures and general medical measures (OPS) and (iii) drug prescriptions that can be categorised using the pharmaceutical central number (PZN) according to the Anatomical Therapeutic Chemical (ATC) system [19]. In claims data, age and sex derive from the health insurance funds' master data.

The underlying methodology for calculating disease frequencies based on routine SHI data consists of three steps: first, the definition concept for measuring the disease frequency in the insured population (see 2.1), second, the development of the case definition for identifying diseased persons (case selection criteria, see 2.2), and third, an age-, sex- and morbidity-adjusted extrapolation to the whole population using regression analysis. This allows statements to be made for all residents in the regions of Germany (see 2.3).

### 2.1 Insured population and concept for determining 1-year myocardial infarction rates

Pseudonymised routine data from around 27 million AOK insurance policyholders from the years 2017 to 2022 is analysed using a cross-sectional approach to identify people affected by a disease [20, 21]. For myocardial infarction, disease frequency is defined as the number of myocardial infarction events occurring during the person-time observed in the study period. In analyses using routine SHI data, it should be considered that the underlying population of insured persons is an open, dynamic cohort with inflows and outflows

due to natural population movements (births, deaths) or changes in an individual's insurance history (e.g. change of health insurance company). Therefore, all calculations are not based on individuals but on observed insurance periods from the respective reporting year in days [22]. In this way, insurance periods of new-borns or deceased persons, as well as those of persons who change insurance, can be considered on a pro rata basis. The period of insurance and the regional allocation of the insured are determined on a quarterly basis. Finally, the population of insured persons, and thus the denominator of the rate estimate, is obtained as the total number of observed quarterly insurance periods for the respective reference year [22].

### 2.2 Case definition for myocardial infarction

A case definition for myocardial infarction events has been developed in collaboration with renowned internal and external experts. The case definition uses diagnoses coded according to ICD-10-GM. The case-based analysis includes only inpatient hospital cases during the analysis period with a corresponding primary diagnosis. We included diagnoses I21 (acute myocardial infarction) and I22 (subsequent myocardial infarction). Because the burden-of-disease calculation requires not only the number of myocardial infarctions but also the duration from the infarction to any subsequent death, publicly available hospital diagnosis statistics for Germany were unsuitable: they capture hospital-treated cases but not the subsequent period [23]. We therefore identified hospital-treated myocardial infarction cases among people insured by the AOK and extrapolated them to the general population (see Section 2.3).

We first identified all hospital-treated myocardial infarction events among people aged 25 years and over and included all individuals in the insured population. This age threshold avoids including possible miscoding in younger age groups in the analyses. Because the burden-of-disease calculation determines average episode durations within a window of up to 28 days, we counted a myocardial infarction as a new acute event only when more than 28 days had elapsed since the preceding myocardial infarction. We used the admission date of each inpatient case to determine this interval. Applying this interval yielded the myocardial infarction episodes relevant to the burden-of-disease calculation; a person could experience more than one episode per year (multiple myocardial infarctions). We report myocardial infarction rates as the number of myocardial infarction episodes per 100,000 people per year. Unlike primary studies that use clinical examination parameters, our results are administrative rates reflecting hospital-treated and billed myocardial infarctions.

### 2.3 Statistical methods

Since the group of policyholders of a health insurance fund is not a random sample of the general population and is therefore not representative of the population [21, 24–27], the specific disease frequencies for each health insurance fund must be extrapolated to the whole population. Due to the regionally different distribution of the population in each health insurance fund, this extrapolation is done by region [28]. In this regression analysis, regionally available statistics on the frequency of inpatient diagnoses and on the demographic structure of the population on the level of the 400 German districts are used as auxiliary information [29, 30]. In this way, in addition to demographic differences, morbidity differences between health insurance funds and the German population can be corrected (morbidity-adjusted) and differentiated by small areas. The method was developed and its plausibility tested using type 2 diabetes as an example [28]. It has been adapted for myocardial infarction to estimate the rates for the whole population of Germany at the level of the 96 spatial planning regions for myocardial infarction events for each reference year. Correlation analysis most frequently selected the three-character ICD codes I10 (essential [primary] hypertension as a secondary diagnosis), E11 (type 2 diabetes as a secondary diagnosis) and I21 (acute myocardial infarction as the primary diagnosis) as relevant covariates. Across the different linear regression models, the median coefficient of determination ($R^2$) was 0.95. We validated the results at spatial-planning-region level against inpatient myocardial infarction frequencies from the diagnosis-related group (DRG) hospital statistics [30] and found a very strong correlation ($R^2 = 0.99$). The estimated case counts were approximately 10 % lower because the present analysis combined myocardial infarction cases occurring within a 28-day period rather than counting them more than once.

For model stability, the extrapolation procedure combines individual age groups into broader age categories, meaning that an estimate is not always available for every 5-year age group. To enable stratification at this level of detail, we applied a dedicated method to model missing age-group-specific values. We transferred the sex-specific rate patterns across 5-year age groups in the AOK population (raw data) to the combined age categories used in the extrapolation and then smoothed the resulting trajectories using spline regression (a B-spline) [31]. We excluded from smoothing any point estimates that the morbidity-adjustment procedure had estimated directly for a specific 5-year age group. In addition, the results are age-standardised using the European Standard Population 2013 for the presentation of maps and time trends [32].

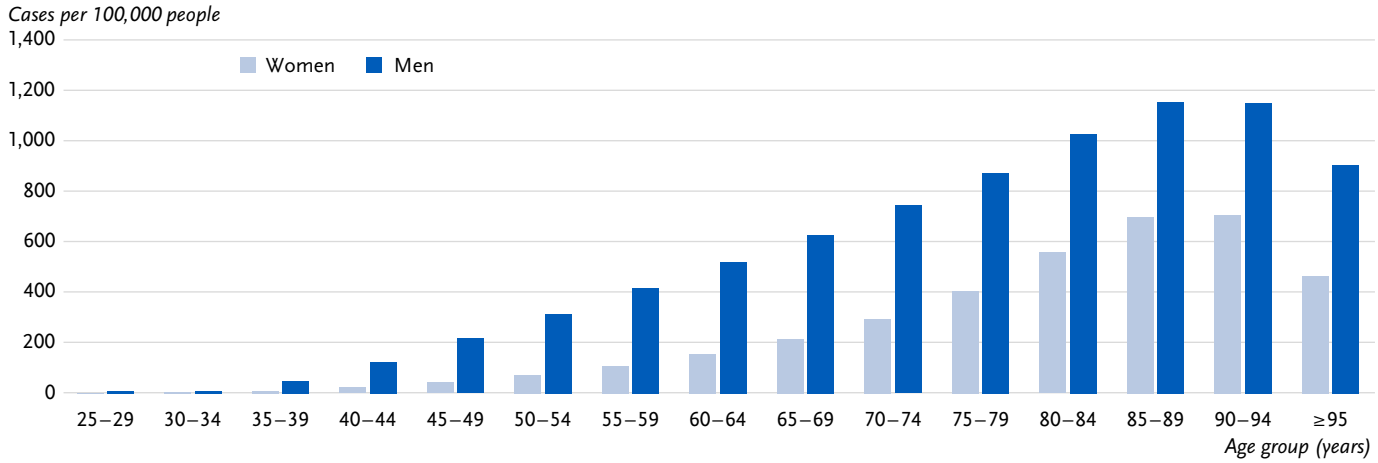



**Figure 1:** Myocardial infarction rates by age and sex (cases among people aged 25 years and over per 100,000 people). Source: Burden of disease study for Germany (AOK claims data 2022, adjusted for age, sex and morbidity and extrapolated to the population of Germany)

## 3. Results

Based on the underlying case definition, the 2022 rate was 270 hospital-treated myocardial infarctions per 100,000 people aged 25 years and over in Germany (administrative rate). The rate was 168 cases in women and 379 in men. The rate of hospital-treated myocardial infarction increased with age and declined only in the oldest age groups. Sex differences remained largely constant across age groups (Figure 1, Supplementary material Table S1).

In 2022, age-standardised rates varied approximately 2.3-fold across spatial planning regions, from 167 per 100,000 people in Upper Elbe Valley/Eastern Ore Mountains to 388 per 100,000 people in Bremen Surrounding Area (Figure 2). Variation at spatial-planning-region level, measured using the interquartile range, was relatively small at 37 cases per 100,000 people, so the middle quartiles showed only minor differences between regions. The variation also decreased steadily in recent years (Supplementary material Table S2). In a small number of regions, standardised myocardial infarction rates remained consistently low throughout

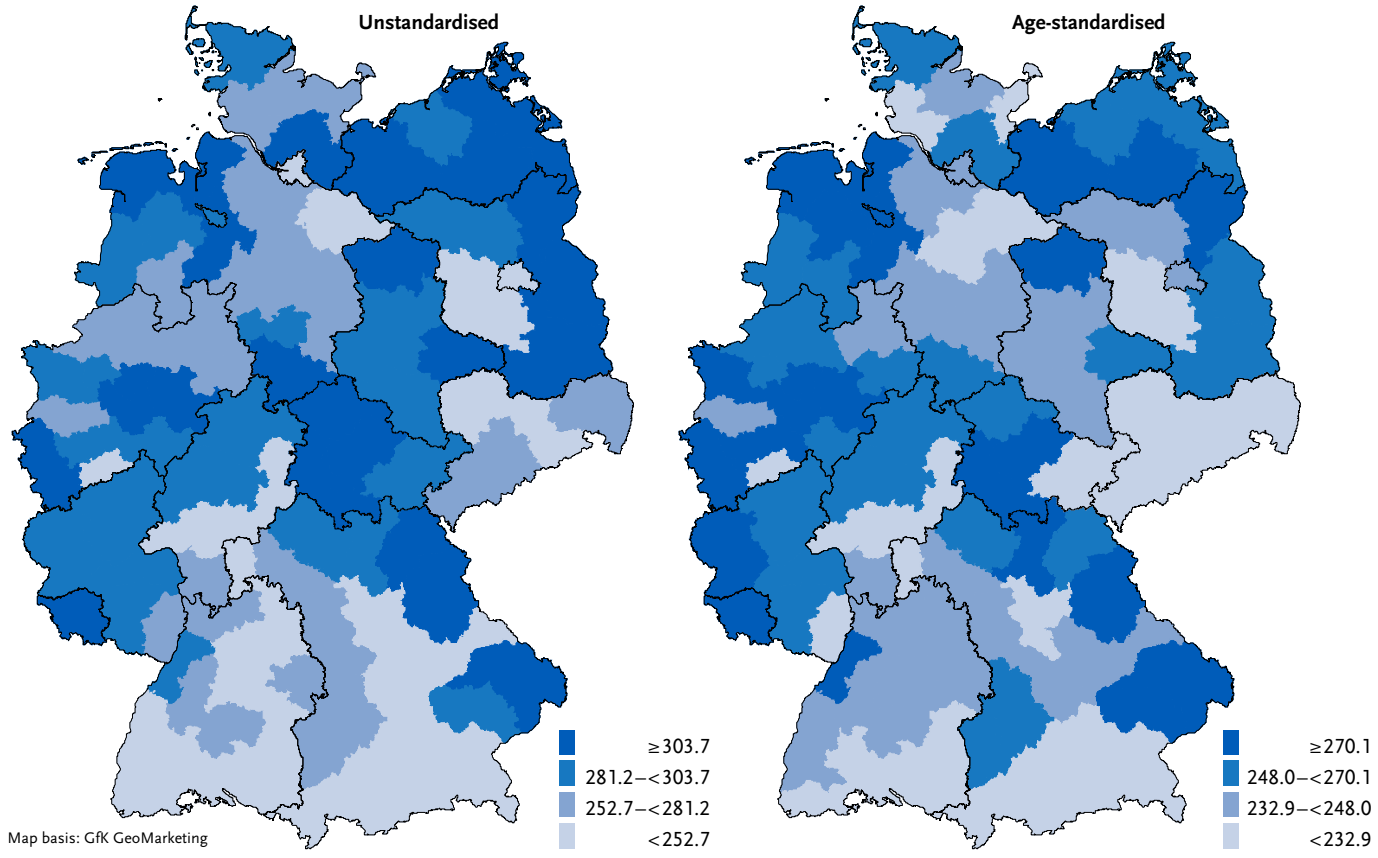



**Figure 2:** Myocardial infarction rates by spatial planning region (cases among people aged 25 years and over per 100,000 people). Source: Burden of disease study for Germany (AOK claims data 2022, adjusted for age, sex and morbidity and extrapolated to the population of Germany)

2017–2022 (e.g., in Saxony or the Munich region) or consistently high (e.g., in north-eastern Bavaria, East Frisia or Saarland).

Age-standardised myocardial infarction rates declined over time. The age-standardised rate was 280 per 100,000 people in 2017 and fell by approximately 11 % to 248 by 2022 (Figure 3, Supplementary material Table S3). Among women, rates declined continuously from 162 to 139 between 2017 and 2022; among men, they declined from 416 to 371 per 100,000 people. The largest decrease occurred between 2019 and 2020.

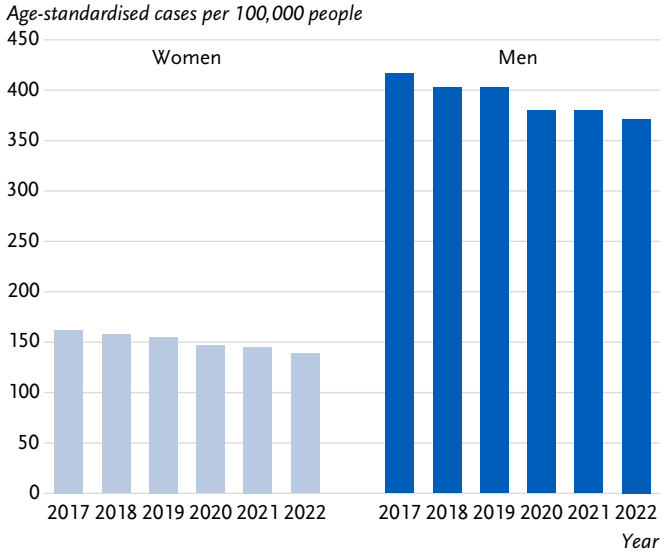



**Figure 3:** Myocardial infarction rates over time (age-standardised cases among people aged 25 years and over per 100,000 people). Source: Burden of disease study for Germany (AOK claims data 2017–2022, adjusted for age, sex and morbidity and extrapolated to the population of Germany)

## 4. Discussion

In 2022, the rate of hospital-treated myocardial infarctions in Germany was 270 per 100,000 people aged 25 years and over. Women had a lower rate than men, with 168 versus 379 myocardial infarctions per 100,000 people. Myocardial infarction rates increased continuously with age. Rates in the population declined between 2017 and 2022. Although age-standardised rates varied 2.3-fold across spatial planning regions in 2022, no clear geographical gradient was evident, and only a few regions had consistently low or high standardised rates throughout the study period.

Myocardial infarction rates reported elsewhere are of a similar magnitude. Based on hospital diagnosis statistics, the German Heart Report reported an unstandardised rate of 226 myocardial infarctions per 100,000 people in the total population in 2022 and 221 in 2023 (acute infarctions only, ICD-10 I21) [33, 34]. Most of the difference reflects the different reference populations: when we relate the figures from the present study to the total population, the myocardial infarction rate is 205 per 100,000 people. The remaining difference largely reflects the counting method used here. We counted myocardial infarction episodes occurring more than 28 days after the preceding infarction only once even when patients were transferred between hospitals, whereas hospital diagnosis statistics may count such cases more than once. Including ICD code I22 (subsequent myocardial infarction within 28 days) additionally had little effect in the present study because physicians assign this code in very few cases and our analysis excluded it within the 28-day window. A study using inpatient myocardial infarction data from AOK Nordost and the Berlin Myocardial Infarction Registry likewise found very close agreement in case counts after combining 13 % of AOK cases at the person level to remove duplicate cases within 28 days [35]. A small residual difference may also arise because the present study extrapolated AOK claims data to the population rather than using hospital diagnosis statistics directly. Data from the Augsburg Myocardial Infarction Registry provide another source of information on myocardial infarction [6]. A detailed comparison of inpatient myocardial infarction case counts for patients residing in the Augsburg region or the city of Augsburg in the present analysis with the corresponding registry counts found marked differences by age and sex (approximately 20 % to 50 % higher in the present study) [6]. By contrast, an additional regional comparison of the extrapolated AOK case counts from the current analysis with national DRG hospital diagnosis statistics showed considerably smaller differences (approximately 10 to at most 20 percentage points lower in the present analysis), which duplicate cases within the 28-day window can explain [35–37].

Epidemiological studies consistently document a higher frequency of coronary heart disease among men than among women [15, 17, 38]. Sex differences in the prevalence of major cardiovascular risk factors such as obesity and smoking are an important explanatory factor [39–41]. However, analyses of myocardial infarction treatment must also consider sex differences in symptom presentation and the greater number of unrecognised or later-diagnosed myocardial infarctions among women [42–44].

Analyses of AOK claims data attributed the decline in myocardial infarction rates during 2020–2022 compared with the period before the COVID-19 pandemic to changes in the use of health-care services resulting from containment measures [45]. Changes in utilisation were less pronounced for ‘severe’ myocardial infarctions accompanied by typical ST-segment elevation on the ECG (STEMI) and more pronounced for ‘less severe’ myocardial infarctions without ST-segment elevation (NSTEMI). Possible explanations discussed for the decline during the pandemic include (i) a deliberate decision not to seek medical care for milder cases,

(ii) a lower probability that another person would notice the myocardial infarction and arrange help because of contact restrictions, and (iii) fewer cases arising as complications of hospital admissions for other reasons, for example major elective operations that hospitals often cancelled or postponed during the pandemic [45]. Direct acute or post-acute consequences of SARS-CoV-2 infection may also have contributed to lasting changes in treatment rates. However, these effects overlap with a longer-term decline in hospital-treated myocardial infarctions in Germany. The downward trend was already evident before the COVID-19 pandemic and continued after 2022 [33]. This is consistent with the long-term decline in myocardial infarction incidence in the Augsburg registry [6] and with the similarly continuous decline in CHD incidence between 2013 and 2021 and CHD prevalence between 2015 and 2024 based on SHI claims data [46, 47]. Thus, hospital-treated myocardial infarctions have shown a sustained long-term downward trend that may partly reflect changes in the risk profile of the population over recent decades [39, 40]. Physical inactivity and tobacco use have both decreased in the population [40]. Other developments, such as increasing obesity, counteract these trends [39, 40]. In addition to behavioural changes, improved medical treatment of metabolic risk factors such as high blood pressure and adverse blood lipid levels may have contributed to declining myocardial infarction rates [34].

The marked regional variation in age-standardised myocardial infarction treatment rates is consistent with the wide regional differences in CHD prevalence across districts and independent cities observed in health insurance claims data [16]. The regional distribution of age-standardised myocardial infarction treatment rates, with consistently low rates in southern parts of Baden-Württemberg and Bavaria, also corresponds to the regional patterns of CHD prevalence and incidence derived from SHI claims data [16, 48, 49]. Within Bavaria, the spatial gradient in myocardial infarction treatment rates, with consistently high rates in the north-east and consistently low rates in the Munich region, likewise corresponds to regional patterns of CHD prevalence and incidence [16, 48, 49]. It is also consistent with the spatial distribution of cardiovascular risk factors such as smoking, obesity and type 2 diabetes, as well as with socioeconomic deprivation [16, 50, 51]. By contrast, other regions with consistently low myocardial infarction treatment rates, such as Saxony, or consistently high rates, such as Saarland, do not show comparably consistent patterns in the regional distribution of CHD prevalence and incidence [16, 48, 49].

Socioeconomic deprivation exhibits a pronounced east–west gradient and therefore does not appear to fully explain the regional differences observed in this study [51]. A study based on DRG hospital diagnosis statistics found higher inpatient myocardial infarction treatment rates among cases involving people aged 65 and older living in rural than in urban regions [52]. Regional differences in socioeconomic conditions and life expectancy explained this difference only partly; Ebeling et al. therefore suggested that secondary prevention, use of primary and specialist care, and other effects of outpatient care may also have contributed [52]. Differences in coding practice could also contribute to regional differences in the observed myocardial infarction rates. However, studies generally rate the validity of inpatient myocardial infarction diagnoses as high [35, 53, 54]. An AOK Sachsen-Anhalt study found substantial spatial differences in inpatient left-heart catheterisation, but no association between examination frequency and the number of inpatient myocardial infarction cases [55]. Differences in transfer rates between regional care networks are also unlikely to explain the regional patterns because we combined treatment episodes for each person within a 28-day period into a single case. Finally, relatively rare events such as myocardial infarction are subject to random regional variation, and these patterns may not remain stable over time. Moreover, variation measured by the interquartile range was relatively small, so regional differences, particularly within the middle quartiles, should not be overinterpreted.

The present analysis relies on routine inpatient SHI data. One advantage of these data is that, compared with the diagnosis-related groups (DRG) statistics published by the German Federal Statistical Office, duplicate case records (e.g., resulting from transfers between hospitals) can be identified and removed. Moreover, some of the typical sources of error associated with primary data collection, such as surveys, are excluded. These include bias due to recall bias, non-response or lower participation of hard-to-reach groups [56]. One limitation that needs to be considered is that SHI routine data mainly contain information relevant for accounting (see 2. Methods). Non-utilisation of health services, lack of documentation of diagnoses and financial incentives to optimise accounting can lead to misclassification and bias in the data [56, 57]. These factors are less relevant for severe acute events such as myocardial infarction, which usually lead to medical contact or hospitalisation. Nevertheless, the data do not capture people who die shortly after the acute event without being admitted to hospital. Estimates suggest that approximately 30 % of myocardial infarction cases in the Augsburg region die outside hospital [6]. In addition, mild infarctions or infarctions diagnosed only retrospectively after a delay because symptoms were subtle may not result in hospital admission [43, 58, 59]. Both issues are of limited relevance to the burden-of-disease calculation for which these data are used: deaths contribute through cause-of-death statistics even when they occur outside hospital, provided myocardial infarction or coronary heart disease is identified as the cause of death, while mild cases are captured in bur-

den-of-disease calculations mainly through sequelae such as heart failure. Finally, routine-data studies can misclassify people with disease, leading to over- or underestimation, when diagnoses are coded incorrectly or not at all. For an event such as a hospital-treated myocardial infarction, however, this possibility is negligible.

Other limitations of the results are related to the statistical methods used for extrapolation and for modelling the age distribution in the 5-year groups. The extrapolation method uses the diagnoses of all hospital admissions in Germany to adjust for differences in morbidity between insurance funds and the population and has been developed and validated for type 2 diabetes [28]. It is thus assumed that the estimated rates no longer reflect the insurance fund specific morbidity, but that of the population. To model age distribution, it was assumed that the age progression of myocardial infarction among AOK insured persons could be applied to the combined age groups from the extrapolation results. The overall myocardial infarction rate remains unaffected by this procedure.

Burden of disease studies place high demands on the data to be used. Among other things, they require the most accurate information possible on the frequency of disease by age, sex and region. For many diseases, routine data from the SHI system are the preferred option for estimating and presenting disease frequencies at the small area level. Thus, burden of disease studies, especially when conducted regularly, provide important basic epidemiological information and fill information gaps. Myocardial infarction is a disease of high public health and health care relevance due to its frequency and treatment demand and is a major cause of disease burden in the population [4].

Heart health in Germany also needs to be considered in an international context. In recent years, life expectancy in Germany has on average increased more slowly than in many other European countries [60, 61]. Evidence suggests that the comparatively high prevalence and, in particular, mortality of cardiovascular disease play a central role. Cardiovascular mortality has declined less in Germany than in other countries [60, 62–64]. Because myocardial infarction accounts for a large proportion of these deaths, improving the detection and treatment of myocardial infarction and achieving a greater reduction in myocardial infarction mortality are important areas for intervention [34]. Targeted health promotion, prevention strategies and care models across all stages of life are essential for reducing existing sex-related and regional differences and improving trends in life expectancy [60, 62, 63].

**Data protection and ethics**
The AOK Research Institute (WIdO) at the AOK Federal Association processes the data on behalf of the AOKs (in accordance with Article 28 EU General Data Protection Regulation (EU-GDPR) in conjunction with §80 SGB X) and uses them for research projects in accordance with §287 SGB V. In this process, the data available at the WIdO are cleansed of direct personal references. In addition to its statutory tasks and its own research for the AOKs, WIdO can also act as an intermediary for third-party research projects. In the context of the present Burden of Disease Study for Germany, only aggregated and extrapolated results of statistical estimations were transferred from the WIdO to the Robert Koch Institute, which no longer contain any personal references and do not fall within the scope of the EU-GDPR.

**Data availability**
The study used pseudonymised claims data from the AOK Research Institute (WIdO) at the AOK Federal Association. This dataset is not publicly available. Requests regarding the aggregated dataset on which the results are based can be made by e-mail to the corresponding author.

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**Individual author contributions**
Substantial contributions to the conception or design of the work: AR, KS, MP, RT, HSt; to the acquisition of the data for the work: KS, GB, HSc; to the analysis of the data for the work: AR, KS, MP, DY; to the interpretation of the data for the work: AR, KS, HSt. Drafting the work: AR, KS, MP, RT, HSt; revising the work critically for important intellectual content: AR, KS, DY, HSt, GB, MP, RT, HSc. Final version of the manuscript read and approved for publication: AR, KS, DY, HSt, GB, MP, RT, HSc.

**Declaration of generative artificial intelligence (AI) and AI-assisted technologies**
The German article was translated into English using ChatGPT (OpenAI, GPT-6). The authors reviewed and edited the translation and take full responsibility for the content of the published article.

**Conflicts of interest**
The authors declare that there are no conflicts of interest.

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