WifOR INSTITUTE

RESEARCH REPORT 2022

The burden of cardiovascular diseases in Germany

Health and socioeconomic burden of selected atherosclerotic cardiovascular disease diagnoses in 2019

AND

Results from a literature review of early evidence on impacts of the COVID-19 pandemic on cardiovascular disease

Imprint

Version 2.1
February 2022

Publishers
WifOR Darmstadt
Rheinstraße 22
D-64283 Darmstadt
Phone: +49 6151 50155-0
E-Mail: contact@wifor.com

Authors
Jennifer Branner
Franziska Sende
Malina Müller
Lukas Mai
Prof. Dr. Dennis Ostwald

Acknowledgement
This project was undertaken with the financial support of Novartis.

Abstract

Background

Cardiovascular diseases (CVDs) are widely prevalent in Germany and are additionally the most common cause of mortality. A large share of these diseases, especially atherosclerotic cardiovascular disease (ACSVD), is preventable. However, up-to-date figures describing the health and socioeconomic burden of ASCVDs in Germany, which possibly show the potential of prevention, are lacking.

Additionally, early evidence suggests that the COVID-19 pandemic could be associated with an increase in CVD risk factors and consequently lead to a higher disease burden.

Objective

We estimate the health and socioeconomic burden of ASCVDs, namely ischemic heart diseases, cerebral infarction and sequelae, and atherosclerosis, in the adult German population for one year. We further explore possible impacts of the COVID-19 pandemic on CVDs in Germany.

Method

In the first part of this study, we use official statistics on mortality, hospitalization, and rehabilitation for ten selected diagnoses (I20-I25, 164-I64, I69, I70) to derive the number of days spent in hospital or rehabilitation, and the number of years of life lost (YLL) for different age and gender groups. These endpoints are translated to losses in paid and unpaid work hours based on labor market statistics and information from the German time use survey. Then they are monetarized according to gross wages.

In the second part, we conduct a literature review on previously identified potential causal links between the COVID-19 pandemic and CVDs, i.e., CVD-related healthcare provision and utilization during the pandemic, behavioral changes in lifestyle risk factors for CVDs, and post-acute implications of a COVID-19 infection. We use PubMed and Google Scholar with a focus on Germany-specific data and peer-reviewed journal articles.

Results

A total of 1.1 million inpatient hospitalizations and 174,005 rehabilitations with 12.7 million days spent in inpatient care, as well as 158,359 deaths resulting in 1.6 million YLL were attributed to ASCVD diagnoses in 2019. The associated socioeconomic burden amounts to 55.0 million hours (€1.1 billion) and 1.9 billion hours (€23.4 billion) of paid and unpaid work lost for inpatient stays, i.e., hospitalization and rehabilitation, and for foregone productivity over remaining life expectancy (YLL), respectively. Over 90% of the estimated socioeconomic burden relates to unpaid work activities.

On the role of the COVID-19 pandemic, 46 articles were included in our literature review after abstract screening of database search results and full-text assessment. Thirty articles covered aspects of healthcare utilization and provision. Twelve articles covered aspects of lifestyle changes in CVD risk factors. Five articles covered CVD-related post-acute implications of a SARS-CoV-2 infection, however, mostly indirect and remain yet to be understood.

Conclusion

In addition to the substantial number of inpatient stays and premature deaths related with ASCVD diagnoses, productivity losses in unpaid work activities are an important aspect of the socioeconomic burden when a large share of patients is above the retirement age. Overall, our estimates show the positive potential that effective prevention strategies could have in reducing the burden.

While the reviewed literature does not allow for inference of long-term trends, it indicates short-term impacts of the COVID-19 pandemic on behavioral CVD risk factors as well as on healthcare for CVDs. With a rapidly growing evidence base, more data will help to better understand different mechanisms and the persistence of effects.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AIS	Acute ischemic stroke
ALI	Acute limb ischemia
ARDS	Acute respiratory distress
ASCVD	Atherosclerotic cardiovascular disease
CI	Confidence interval
COVID-19	Coronavirus disease 2019
CMR	Cardiovascular magnetic resonance
CV event	Cardiovascular event
CVD	Cardiovascular disease
ESP 2013	Revised European Standard Population 2013
GVA	Gross value added
HF	Heart failure
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th revision
ICH	Intracerebral hemorrhage
IS	Ischemic stroke
IVT	Intravenous thrombolysis
MeSH	Medical Subject Headings
MT	Mechanical thrombectomy
NSTEMI	Non-ST-elevation myocardial infarction
NYHA	New York Heart Association
SARS-CoV-2	Severe acute respiratory syndrome coronavirus type 2
STEMI	ST-elevation myocardial infarction
TIA	Transient ischemic attack
YLL	Years of life lost

1 Background and study objectives

Cardiovascular diseases (CVDs) play a major role in the health status of the German population. Firstly, CVDs are the most common cause of mortality in Germany, responsible for 34.3 percent of all deaths in 2020 (Statistisches Bundesamt (Destatis), 2021h). Moreover, chronic CVDs are widely prevalent among Germans (Dornquast et al., 2016) and have a particularly high public health relevance as a cause of morbidity and healthcare expenditures (Statistisches Bundesamt (Destatis), 2017a). In addition to the cost and inconvenience of medical check-up visits, therapy, and hospitalizations, CVD patients can suffer from long-term disability and reduced quality of life. This is often accompanied by a high degree of functional impairment, although the disease severity varies widely across different CVDs. This poses not only a burden on patients, but also has economic and societal consequences due to absence from work or from other activities, including productive tasks such as housekeeping, childcare, or voluntary services.

As a large share of CVDs is preventable (World Health Organization, 2021), there is great opportunity to reduce this burden (Waterall, 2019). Atherosclerotic cardiovascular disease (ACSVD) is considered the primary preventable form of CVD. Preventable risk factors for atherosclerosis range from obesity, lack of physical activity, unhealthy diet, and uncontrolled blood pressure to cholesterol (LDL-C) (Kuhlmann et al., 2015; Mach et al., 2020; Robert Koch-Institut & Statistisches Bundesamt (Destatis), 2006; World Health Organization, 2021). Therefore, prevention strategies may include early and continuous health education, communities that promote healthy nutrition, regular physical activity, and equal access to effective drugs and therapies for all societal groups.

However, reliable and up-to-date data describing the health and socioeconomic burden of ASCVDs in Germany, such as myocardial infarction or ischemic stroke, are lacking. This can hinder awareness of the potential of prevention to mitigate detrimental consequences and delay the establishment of nationwide prevention strategies. In the face of an aging society, such strategies might be particularly important.

Additionally, early evidence suggests that the COVID-19 pandemic and associated containment measures could lead to an increase in CVD risk factors, both via SARS-CoV-2 infection and behavioral changes, and could consequently lead to a higher disease burden in the future (Mattioli et al., 2020; Woods et al., 2020; Zeymer et al., 2021; Saleh et al., 2020; Böhm et al., 2020).

Therefore, this study pursues two objectives:

(1) Estimate the health and socioeconomic burden of ASCVDs in Germany
   - Provide reliable and up-to-date figures
   - Include productivity losses (indirect costs) in terms of both paid und unpaid work

(2) Explore the role of the COVID-19 pandemic in the future burden of CVDs in Germany
   - Provide an overview of the current literature on causal links between the COVID-19 pandemic and CVDs
   - Evaluate the suitability of existing evidence to derive trends for the German general population (generalizability)

The report describes both parts of the study separately, including the methods and data used as well as the respective results.

2 Estimating the health and socioeconomic burden

The aim of the first part of the study is to quantify the health and socioeconomic burden of ASCVDs in Germany. To establish an appropriate disease definition, we distinguish between CVDs that are primarily caused by atherosclerosis and those with other primary causes. We select ten diagnoses relating to documented ASCVD to be included in the analysis (Table 1).

Table 1: Included ASCVD diagnoses and respective ICD-10-GM code

	Diagnosis	ICD-10-GM code
Ischemic heart diseases	Angina pectoris	I20
	Acute myocardial infarction	I21
	Subsequent myocardial infarction	I22
	Current complications following acute myocardial infarction	I23
	Other acute ischemic heart diseases	I24
	Chronic ischemic heart disease	I25
Cerebral infarction and sequelae	Ischemic stroke	I63
	Stroke, not specified as hemorrhage or infarction	I64*
	Sequelae of cerebral infarction	I69*
Atherosclerosis	Including peripheral arterial disease	I70

Note: ICD-10-GM 2019: International Statistical Classification of Diseases and Related Health Problems, 10th revision, German Modification; *The diagnosis does not specify the type of stroke. 82.5% of cases with a not further specified stroke diagnosis were assumed to be ischemic strokes (Robert Koch-Institut, 2017).

The burden of disease can relate to different aspects of impaired health. We use the term health burden to describe different indicators of morbidity and mortality associated with a disease. Within this framework, socioeconomic burden is defined as losses in paid and unpaid work due to ASCVDs. We also refer to lost paid and unpaid work hours as productivity losses.

2.1 Methodology and data collection

To estimate the health and socioeconomic burden associated with ASCVDs, we focus on the German adult population. All included cases relate to persons that are 20 years old or older. There is no upper age limit.

The time horizon of analysis is the year 2019. It is the calendar year which provides the most current data that is unbiased by the COVID-19 pandemic and its far-reaching impact. Thus, this year is best suited for establishing a baseline for the burden of ASCVDs prior to the pandemic.

Inpatient hospitalizations, rehabilitation cases, and premature mortality associated with the selected diagnoses are chosen as the relevant health outcomes in the context of this study. Their occurrence in 2019 represents the basis of the calculations. We use data from hospital diagnosis records, rehabilitation facilities records, and cause of death

statistics (Statistisches Bundesamt (Destatis), 2021b, 2021c, 2021d, 2021g). This data is part of the national health reporting in Germany. It is highly reliable, regularly updated, and published in aggregated form by the German Federal Statistical Office (Destatis). All data on these health outcomes is available separately by 5-year-age and gender groups, as well as by federal states for the ten selected diagnoses.

We use the length of hospital or rehabilitation facility stay, and premature mortality to establish a link between health outcomes and socioeconomic burden. The basic idea is that each associated event leads to immediate absenteeism from paid work and thus to a loss in production (or rather productivity potential in the case of premature mortality). Additionally, patients who are hospitalized, attend rehab, or die prematurely do not perform daily activities, including such tasks as housekeeping, childcare, informal care, or voluntary services.

These latter activities are typically referred to as unpaid work. Unpaid work is defined as a set of productive activities performed without monetary remuneration that could be carried out by a third person instead, e.g., by a hired housekeeper (Reid, 1934). Like paid work, unpaid work contributes to a society's prosperity (Krol et al., 2016; Miranda, 2011).

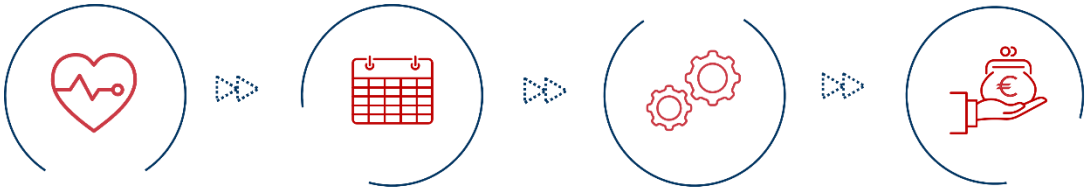
We use a set of different labor market and national accounts statistics to determine the losses in paid and unpaid work hours that occur during hospitalization, rehabilitation, or premature death associated with ASCVDs. This data refers to the German population and is age and gender specific. Unlike the health-related data, the data sources on socioeconomic parameters do not offer stratification on a regional level and are often limited in terms of a catch-all category for older age groups. An overview of the health data sources, and socioeconomic input parameters used in the main part of our analysis, the so-called base case, is shown in the appendix (Annex 1).

The performed calculation steps and respective data sources are summarized in the following section. Analyses are carried out using R version 4.0.3 (2020-10-10) (R Core Team, 2020), RStudio Version 1.4.1103 (RStudio Team, 2021), and Microsoft Excel 2016.

2.1.1 Calculating the value of lost productive time

The health and socioeconomic burden is calculated sequentially. The calculation consists of four main steps (Figure 1). As the starting point of our analysis, we determine the number of death cases, inpatient hospitalizations and rehabilitations due to each included ASCVD diagnosis in 2019 (Statistisches Bundesamt (Destatis), 2021b, 2021c, 2021g, 2021d).

Figure 1: Stylized depiction of the main steps for estimating the burden of ASCVDs



1 – Disease events in the year 2019 in German adults

- Hospital inpatient cases
- Rehab cases
- Death cases

2 – Time loss of patients

- Days spent in hospital and rehab
- Years of life lost (YLL)

3 – Productivity loss

Hours lost due to absence days and foregone productivity potential

- Paid work
- Unpaid work

4 – Valuing lost productive time

Monetizing work hours according to

- Average gross wage
- Replacement cost with specialist's gross wage for unpaid work

In a second step, we assess the associated number of days spent in hospitals and in rehabilitation facilities based on the same sources and calculate the years of life lost (YLL) due to premature mortality. The concept of YLL is based on the life expectancy at a certain age. The difference between the estimated remaining life expectancy in years (Statistisches Bundesamt (Destatis), 2021e) and the actual age at the time of death (Statistisches Bundesamt

(Destatis), 2021d) is reported as the number of YLL. The number of disease events, the lost life years, and the time that patients spend in a healthcare facility constitute aspects of the health burden of ASCVDs.

In a third step, we calculate the average potential for productivity in the respective age and gender groups according to paid and unpaid working volume in the German population. We use data on the employment rate (Eurostat, 2021), on average actual working hours (Institut für Arbeitsmarkt- und Berufsforschung (IAB), 2021), and from the German Time Use Survey (Statistisches Bundesamt (Destatis), 2017b) to determine the average age and gender specific hours of paid and unpaid work performed each day. We multiply these hours by the number of hospital and rehabilitation days to determine the overall productivity loss associated with these health outcomes. To calculate the productivity losses due to YLL, we determine in which age groups the remaining life expectancy falls based on the age at the time of death. Assuming that productivity patterns (age and gender specific employment rate, hours worked, amount of unpaid work) in the future will not differ from the current status quo, we then value the YLL at the average annual working volume of the corresponding age group.

In a last step, we attach a monetary value to productivity loss by applying the human-capital-approach. The human-capital-approach treats labor as an asset and considers poor health as a loss in production (potential) to the economy over the remaining productive lifetime. The loss in human capital is measured as the present value of lost time. Thus, the lost hours of paid work were valued at the average gross hourly wage (Statistisches Bundesamt (Destatis), 2021f). The hours of unpaid work were valued according to the replacement cost approach with specialist's wage (also known as proxy good approach). That is, unpaid work activities were assigned to the industry sector of their closest market substitute and valued at the respective gross hourly wage (Hofmann, 2015; Statistisches Bundesamt (Destatis), 2021f). The monetary value of productivity losses associated with YLL are then discounted with a discount rate of 3.0%.

2.1.2 Adjustment for population size, age distribution, and gender ratio between the German federal states

We obtain all data on the included health outcomes stratified by federal state and estimate the health and socioeconomic burden at this regional level. That is, we determine the number of hospitalizations, rehabilitations, and death cases, as well as the number of productive hours lost for each of the 16 German federal states.

While these figures represent the burden of ASCVDs in each federal state in absolute terms, such a comparison does not provide much informative value. Because of the differences in population size between federal states, the total number of ASCVD-related events differs considerably. In addition, the population of the federal states differs in age and gender distribution (Figure 2). Most notably, the population of the new states is characterized by an older demographic. Overall, there is a higher share of women than men over the age of 65 in all federal states.

To enable a tentative comparison between federal states of different population sizes, results on the health burden of ASCVDs are additionally presented as a crude rate per population of 100,000. We use the average population in 2019 in each federal state for determining these crude rates for each health outcome. The average population in 2019 is calculated by taking the mean values of the cutoff dates December 31, 2018, and December 31, 2019, which are both projections based on the most recent census of 2011 (Statistisches Bundesamt (Destatis), 2021a).

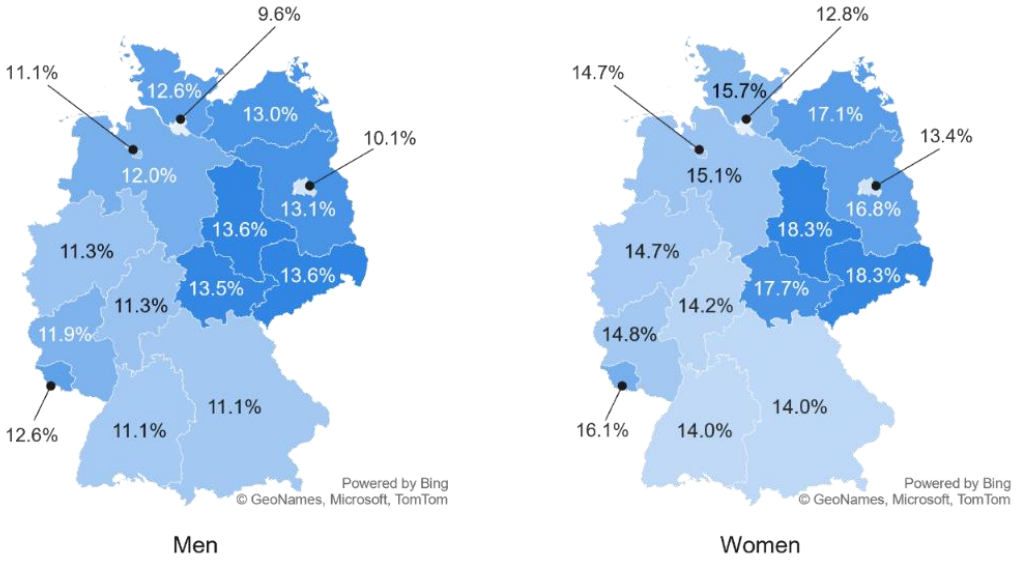
The calculated crude rates are also adjusted for age and gender distribution in a second step. We use the Revised European Standard Population 2013 (ESP 2013) as a reference population (European Union, 2013). The ESP 2013 is a fictitious population distribution. Women and men are assumed to have an identical age distribution with a gender ratio of 1:1.

Thus standardized rates can be compared between federal states as well as between European countries as commonly done in health reporting (Gesundheitsberichterstattung des Bundes, 2021). However, many relevant impact factors on health in general and on ASCVDs in specific are still not accounted for after such an adjustment – which is why standardized rates and differences between regional entities must be interpreted with caution. Due to the focus

on adults 20 years and older in this study, a minor underestimation in standardized rates compared to studies including children and adolescents can be assumed.

Results on the socioeconomic burden are further presented as a crude rate per population of 100,000 in addition to the results in absolute terms (total number). We do not report standardized rates of productivity loss. Since the socioeconomic burden estimate is based on input parameters for the overall German population, this would not provide an added informative value.

Figure 2: Share of persons 65 and older in the adult population in each federal state for 2019



Source: Own calculation based on data provided by Statistisches Bundesamt (Destatis) (2021a). Rounded numbers.

2.1.3 Alternative scenarios to test model robustness

To test the robustness of the base case results, we estimated the socioeconomic burden while varying certain input values one at a time. Comparing the results of alternative scenarios against our base case provides information about the impact of uncertainty around the main socioeconomic input parameters and assumptions. Such a comparison also indicates how a chosen methodological approach influenced the results.

We formulated eleven alternative scenarios to the base case (Table 2). These scenarios represent

- different assumptions on the productivity potential within the relevant population,
  - employment rate of persons 65 and older is zero (no paid work)
  - average working volume in both paid and unpaid work activities is reduced by 20% (health-related work impairment)
- different time horizon for which productivity losses are considered,
  - friction-cost-approach applied with an average friction period of 127 days in 2019 (Bundesagentur für Arbeit (BA), 2020)
- different approaches to monetarize productive time,
  - minimum wage in Germany of € 9.60 (as of July 1, 2021)
  - gross compensation of employees per day according to *Hannoveraner Konsens* (von der Schulenburg et al., 2008) of € 123.19 in 2019 (Statistisches Bundesamt (Destatis), 2020b)

Table 2: Alternative scenarios for estimating the socioeconomic burden with varied assumptions or input parameters

Scenario	Employment rate	Working time	Unpaid work	Monetary value paid work	Monetary value unpaid work	Discount rate for monetary value of YLL
Base case scenario (see Annex 1)	Same as German population (2019)	Same as German population (2019)	Same as German population (2012)	Average gross wage (2019) € 27.75	Replacement cost with specialist's gross wage (2019)	3.0%
Retirement at 65	No paid work for ages 65 years and older	No paid work for ages 65 years and older	Base case scenario	Base case scenario	Base case scenario	Base case scenario
Reduced paid work	Base case scenario	Reduced paid work volume -20%	Base case scenario	Base case scenario	Base case scenario	Base case scenario
Friction-cost-approach	Friction period of 127 days	Friction period of 127 days	Base case scenario	Base case scenario	Base case scenario	Base case scenario
Reduced unpaid work	Base case scenario	Base case scenario	Reduced unpaid work volume -20%	Base case scenario	Base case scenario	Base case scenario
Minimum wage	Base case scenario	Base case scenario	Base case scenario	Minimum wage € 9.60	Minimum wage € 9.60	Base case scenario
Recommendation in *Hannoveraner Konsens*	Base case scenario	Evaluation of lost days, not working hours	Base case scenario	Gross compensation of employees per day € 123.19	Base case scenario	Base case scenario
Generalist wage	Base case scenario	Base case scenario	Base case scenario	Base case scenario	Replacement cost with generalist's gross wage € 19.07	Base case scenario
Gross value added (GVA)	Base case scenario	Base case scenario	Base case scenario	GVA per working hour € 54.78	Replacement cost with specialist's GVA	Base case scenario
Discount rate 0%	Base case scenario	Base case scenario	Base case scenario	Base case scenario	Base case scenario	0.0%
Discount rate 5%	Base case scenario	Base case scenario	Base case scenario	Base case scenario	Base case scenario	5.0%
Minimum-productivity-loss	No paid work for ages 65 years and older	Reduced paid work volume -20%	Reduced unpaid work volume-20%	Minimum wage € 9.60	Minimum wage € 9.60	5.0%

Note: The term employment rate stands for the economically active population as percentage of the total population, also known as activity rate.

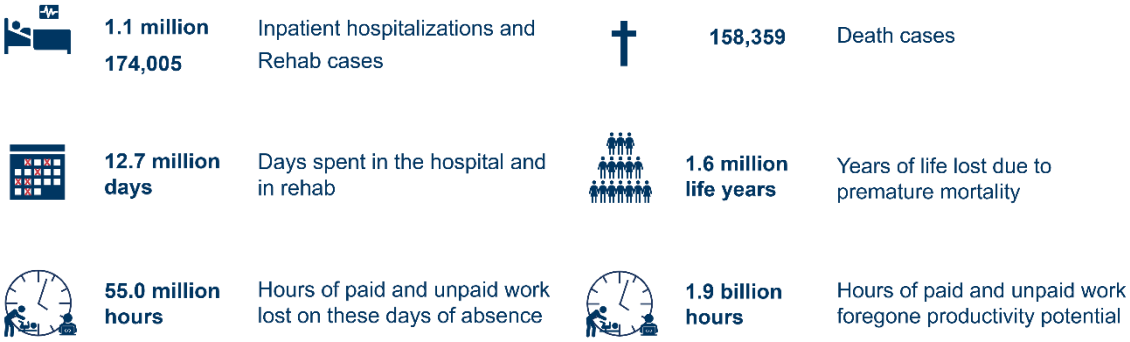
- replacement cost approach with generalist wage, i.e., € 19.07 for health and care professions (Statistisches Bundesamt (Destatis), 2020a)
- gross value added (GVA) per working hour of € 54.78 (Statistisches Bundesamt (Destatis), 2020b)

- different discount rates for future productivity losses associated with YLL (0.0%, 5.0%).

As information on the uncertainty around work impairment in patients who suffer an ASCVD diagnoses compared to the German population average was not available, paid and unpaid working volume were varied by 20%. Calculations with minimum wages for paid and unpaid work were included to provide lower-bound estimates of the socioeconomic burden in monetary terms. We did, however, also include a minimum-productivity-loss scenario, in which all main socioeconomic input parameters were varied simultaneously. This scenario is intended to show a minimum estimate of the socioeconomic burden of ASCVD if the main input parameters were all to deviate in the direction of a smaller productivity loss in reality.

2.2 Results on the health and socioeconomic burden

Figure 3: Overview of the results on the health and socioeconomic burden of ASCVDs in Germany for 2019



Source: Own calculation. Rounded numbers.

2.2.1 The highest overall health burden is with men, but women account for the most deaths and inpatient care in the oldest age groups

In 2019, a total of 1.1 million inpatient hospitalizations, 174,005 rehabilitations, and 158,359 deaths were attributed to one of the ten selected ASCVD diagnoses. These events were associated with approximately 8.3 million days spent in a hospital and 4.4 million days spent in a rehabilitation facility. Approximately 1.6 million years of life were lost (undiscounted) to premature mortality. This equates to an average of 9.9 YLL per registered death case.

The gender specific distribution of the health burden shows that the highest number of ASCVD-related events is found in men: 696,153 hospitalizations (63.7%) in men and 396,810 in women (36.3%), 116,268 rehabilitations (66.8%) in men and 57,737 in women (33.2%), 83,505 deaths in men (52.7%) and 74,854 in women (47.3%). The number of YLL is also higher in men with 923,806 YLL (58.9%) and 643,723 YLL (41.1%) in women. This reflects a higher share of deaths occurring under the age of 65 in men (12.6%) than in women (3.7%).

More detail on the total number of events and length of stay (in days) is shown by age, gender, and primary diagnoses in Figure 4: Here it is clear that among the included diagnoses, ischemic heart diseases (ICD-10-GM codes I20-I25) are responsible for the highest number of deaths and hospitalizations in men and women. While this is also the case

for rehabilitations in men, cerebral infarction (ICD-10-GM codes I63, I64, I69) accounted for most rehabilitations in women. Figure 4 also shows that although there were over six times more ASCVD-related hospitalizations in 2019, days spent in rehab make up 34.8% of the overall time loss of patients, that is time spent in short-term inpatient care. This can be explained by differences in the average length of stay: 7.6 days for an inpatient hospitalization and 25.5 days for a rehabilitation. Finally, the absolute number of fatalities rises with increasing age. For men, however, the most deaths occur in the age group 80-84 years. When depicting the health burden in relative numbers for different age groups (as a crude rate per population of 100,000), the highest mortality rates are observed in the oldest age group (see Annex 2 in the appendix).

2.2.2 The socioeconomic burden mainly affects unpaid work activities

The socioeconomic burden of ASCVDs overall and per case is shown in Table 3. Hospitalizations and rehabilitations due to ASCVD correspond to an estimated 14.4 million hours of paid work lost. This is equivalent to 0.9 hours of paid work lost per day spent in a hospital and 1.6 hours lost per day spent in a rehabilitation facility. The difference in time lost per day between hospitalization and rehabilitation is due to two factors: Patients in rehab are younger on average, and the mean length of stay is more than three times as long (25.5 days) than in hospital (7.6 days). In addition, these inpatient stays correspond to 40.6 million hours of unpaid work lost. That is 3.2 hours per day that a patient would otherwise spend on productive activities such as housekeeping, childcare, or volunteering. Three-quarters (73.9%) of the estimated productivity loss due to hospitalizations and rehabilitations in 2019 relates to these unpaid work activities.

YLL correspond to losses in productive potential of 159.5 million hours of paid work and 1.8 billion hours of unpaid work. This means that each death is associated with 1,007 hours of lost productivity potential in paid work and 11,219 hours in unpaid work. Reflecting the underlying age distribution and the relatively small proportion of deaths and inpatient care in age groups engaged in paid work, over 90% of the overall estimated socioeconomic burden relates to unpaid work activities. This result highlights the importance of including unpaid activities in such types of analyses.

Valuing the aggregated losses in paid and unpaid work in terms of average gross wage corresponds to a monetary impact of € 1.1 billion associated with hospitalization and rehabilitation. The monetary value of foregone productivity potential over YLL is estimated at € 23.4 in the base case scenario.

Table 3: Socioeconomic burden associated with ASCVD diagnoses in 2019

	Paid and unpaid work productivity lost [in hours]		**Monetary value of productivity losses* [in Euro]**	
Productivity loss associated with	Paid work	Unpaid work	Paid work	Unpaid work
Inpatient hospitalizations	7.4 m hours	26.6 m hours	€ 205.0 m	€ 485.5 m
Per case	*6.8 hours*	*24.4 hours*	*€ 187*	*€ 444*
Rehabilitations	7.0 m hours	14.0 m hours	€ 194.2 m	€ 258.7 m
Per case	*40.2 hours*	*80.4 hours*	*€ 1,116*	*€ 1,486*
Years of life lost	159.5 m hours	1.8 bn hours	€ 2.0 bn	€ 21.4 bn
Per death case	*1,007 hours*	*11,219 hours*	*€ 12,927*	*€ 134,905*

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis), Eurostat, and Institut für Arbeitsmarkt- und Berufsforschung (IAB) (see section 2.1). Rounded numbers.
*Monetary value of productivity losses associated with premature mortality are discounted with a discount rate of 3.0%.
m: million; bn: billion

Figure 4: Health burden associated with selected ASCVD diagnoses in 2019

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis) (see section 2.1). Rounded numbers.

2.2.3 Results for the German federal states

Hospitalizations, rehabilitations, and death cases due to an ASCVD diagnoses in each federal state for 2019 are shown in Figure 5, Figure 6, and Figure 7. The federal states North Rhine-Westphalia, Bavaria, and Baden-Württemberg, which have the largest surface area and population size, show the highest total numbers of inpatient hospitalizations, rehabilitations, and death cases. The lowest total number of inpatient hospitalizations, rehabilitations, and death cases is observed in the city state Bremen.

However, looking at the crude rates per 100,000, we see a different picture in terms of relative health burden (regardless of population size). The city state Bremen and the small federal state Saarland, followed by Saxony-Anhalt, have the highest rates of inpatients hospitalization. Saxony-Anhalt, Saarland, and Thuringia have the highest rates of rehabilitations. Saxony-Anhalt, Saxony, and Mecklenburg-Western Pomerania show the highest mortality rates due to ASCVDs. Baden-Württemberg shows the lowest rate for inpatient hospitalizations, and the Hanseatic City of Hamburg shows the lowest rate for rehabilitation and death cases.

After adjusting for age distribution and gender ratio according to the ESP 2013, Bremen, Berlin, and Saarland are the top three federal states with the highest standardized rates of inpatient hospitalization. Saarland, Saxony-Anhalt, and Thuringia have the highest standardized rates of rehabilitations. Saxony-Anhalt, Mecklenburg-Western Pomerania, and Saxony show the highest standardized rates of ASCVD mortality. In contrast, Saxony shows the lowest standardized rate of inpatient hospitalizations. The lowest standardized rates for rehabilitation and mortality are observed in the Hanseatic City of Hamburg. An overview of number of hospitalizations, rehabilitation, and death cases due to an ASCVD diagnoses in each federal state can be found in the appendix (Annex 3).

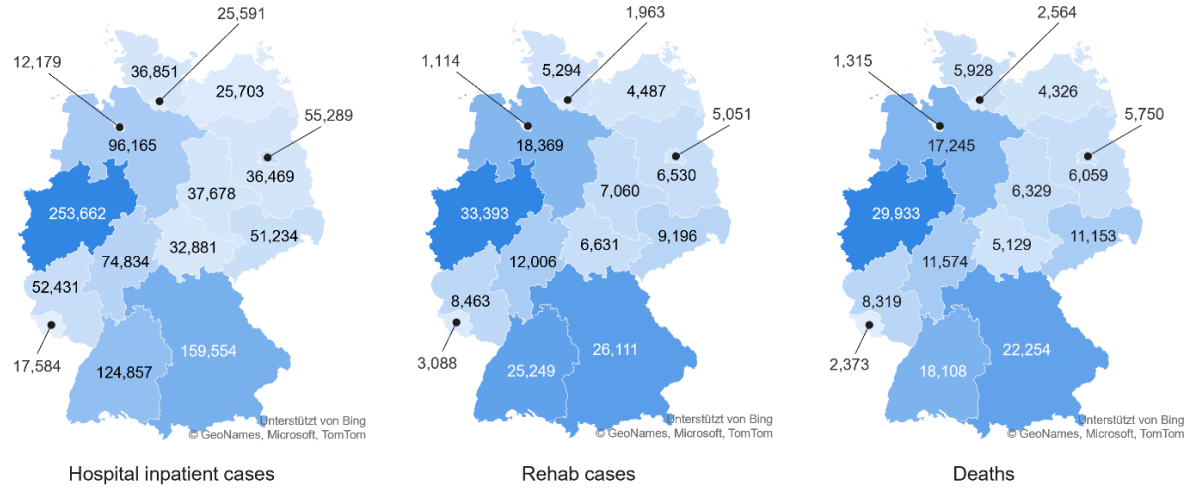
The estimated socioeconomic burden in paid and unpaid work hours lost due to ASCVD diagnoses in 2019 in each federal state and the respective monetary value are presented in Table 4.

2.2.4 Robustness to changes in main assumptions

The sensitivity of the estimated monetarized socioeconomic burden concerning the uncertainty around our main input parameters and assumptions is depicted in Figure 8. The bar charts can be interpreted similarly to a tornado diagram: Each bar represents an alternative scenario estimate of the monetarized socioeconomic burden. The bars are ordered so that the scenario with the largest positive divergence from the base case scenario (higher estimate) appears at the top of the chart. The scenario with the largest negative divergence from the base case scenario (lower estimate) appears at the bottom of the chart.

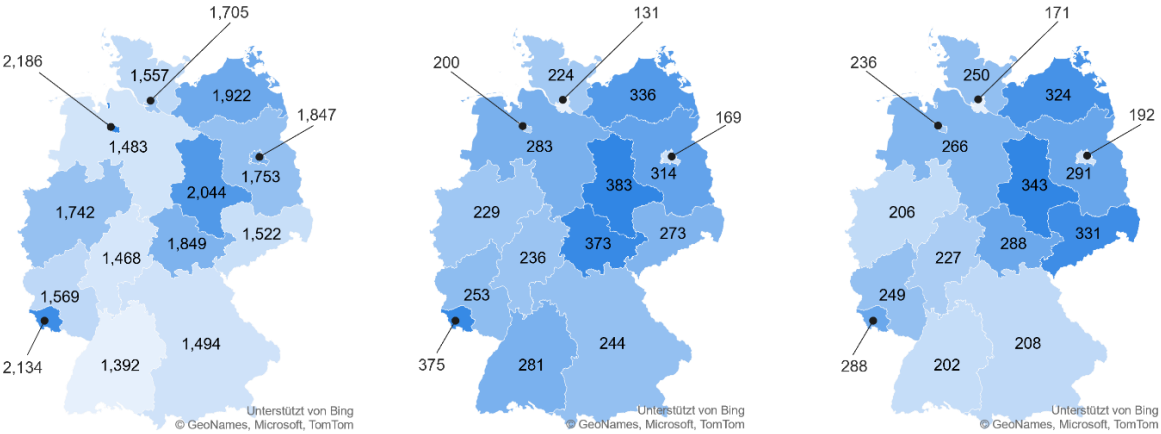
The illustrations in Figure 8 show that, apart from the worst-case scenario, the chosen monetary measure of work productivity (GVA per working hour vs. minimum wage per working hour) introduces the highest level of uncertainty in our calculation. The results are more stable to changes in the assumptions on working volume, for example, the employment rate after age 65.

Figure 5: Health burden in each federal state for 2019 (absolute number of cases)



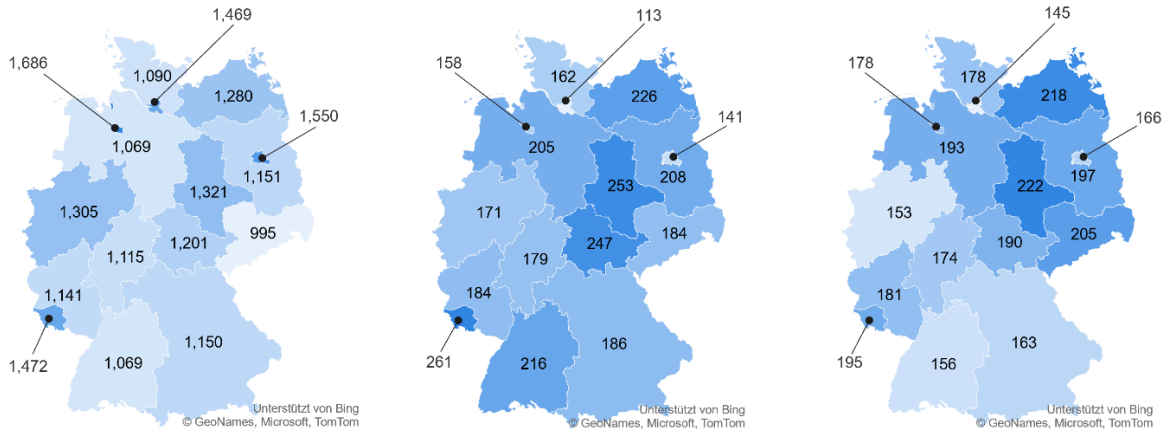
Hospital inpatient cases | Rehab cases | Deaths

Figure 6: Health burden in each federal state for 2019 (crude rate per 100,000 inhabitants)



Hospital inpatient cases | Rehab cases | Deaths

Figure 7: Health burden in each federal state for 2019 (standardized rate per 100,000 inhabitants)



Hospital inpatient cases | Rehab cases | Deaths

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis), Eurostat, and Institut für Arbeitsmarkt- und Berufsforschung (IAB) (see section 2.1). Rounded numbers.
Results were adjusted for age distribution and gender ratio according to the European Standard Population (European Union, 2013) to present the standardized rate per 100,000 inhabitants.

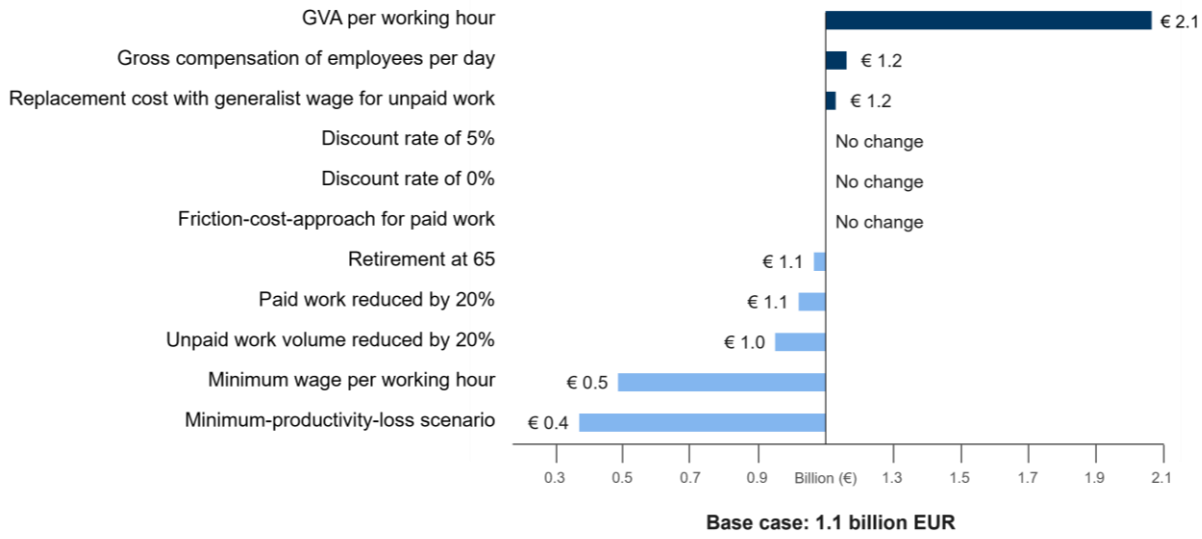
Table 4: Estimated paid and unpaid work hours lost due to ASCVD diagnoses in each federal state with the respective monetary value (2019)

Federal state	Work hours lost - inpatient hospitalizations and rehabilitations [in hours]		Monetary value of productivity losses - inpatient hospitalizations and rehabilitations [in Euro]		Work hours lost - premature mortality [in hours]		Monetary value of productivity losses - premature mortality* [in Euro]	
	Absolute number	Crude rate per 100,000	Absolute number	Crude rate per 100,000	Absolute number	Crude rate per 100,000	Absolute number	Crude rate per 100,000
Schleswig-Holstein	1,807,348	76,372	37,704,021	1,593,228	73,963,980	3,125,435	888,722,120	37,553,998
Hanseatic City of Hamburg	1,120,809	74,659	23,058,301	1,535,951	30,033,027	2,000,549	366,514,364	24,414,125
Lower Saxony	5,155,626	79,519	107,632,163	1,660,100	212,458,665	3,276,925	2,560,310,430	39,489,780
Bremen	556,137	99,816	11,469,928	2,058,631	16,643,924	2,987,263	199,526,286	35,811,116
North Rhine Westphalia	12,413,568	85,262	257,761,986	1,770,432	358,299,864	2,460,974	4,350,564,085	29,881,740
Hesse	4,010,436	78,678	83,352,974	1,635,235	137,575,836	2,698,990	1,677,550,242	32,910,514
Rhineland-Palatinate	2,630,966	78,720	54,965,347	1,644,585	102,291,162	3,060,593	1,235,415,201	36,964,120
Baden-Württemberg	6,488,646	72,315	135,341,696	1,508,360	216,198,599	2,409,496	2,628,727,580	29,296,713
Bavaria	7,765,776	72,719	161,521,932	1,512,492	270,769,927	2,535,491	3,282,994,628	30,741,985
Saarland	951,408	115,440	19,863,785	2,410,183	29,211,849	3,544,435	352,509,697	42,771,946
Berlin	2,123,558	70,941	43,708,101	1,460,134	77,055,378	2,574,150	910,940,080	30,431,314
Brandenburg	2,110,905	101,475	43,539,174	2,093,016	75,043,418	3,607,489	904,915,739	43,501,131
Mecklenburg-Western Pomerania	1,258,036	94,071	26,434,301	1,976,656	57,144,638	4,273,059	679,749,035	50,829,046
Saxony	2,778,731	82,569	57,099,261	1,696,690	131,079,966	3,895,008	1,603,207,632	47,638,914
Saxony-Anhalt	1,945,597	105,564	40,596,791	2,202,695	82,404,210	4,471,076	982,069,232	53,284,973
Thuringia	1,895,410	106,574	39,254,603	2,207,190	65,926,570	3,706,889	786,934,907	44,247,412
Total	***55,012,956***	***-***	***1,143,304,363***	***-***	***1,936,101,011***	***-***	***23,410,651,257***	***-***
Average value	***-***	***87,168***	***-***	***1,810,349***	***-***	***3,164,239***	***-***	***38,110,552***

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis), Eurostat, and Institut für Arbeitsmarkt- und Berufsforschung (IAB) (see section 2.1). Rounded numbers.
*Monetary value of productivity losses associated with premature mortality are discounted with a discount rate of 3.0%.

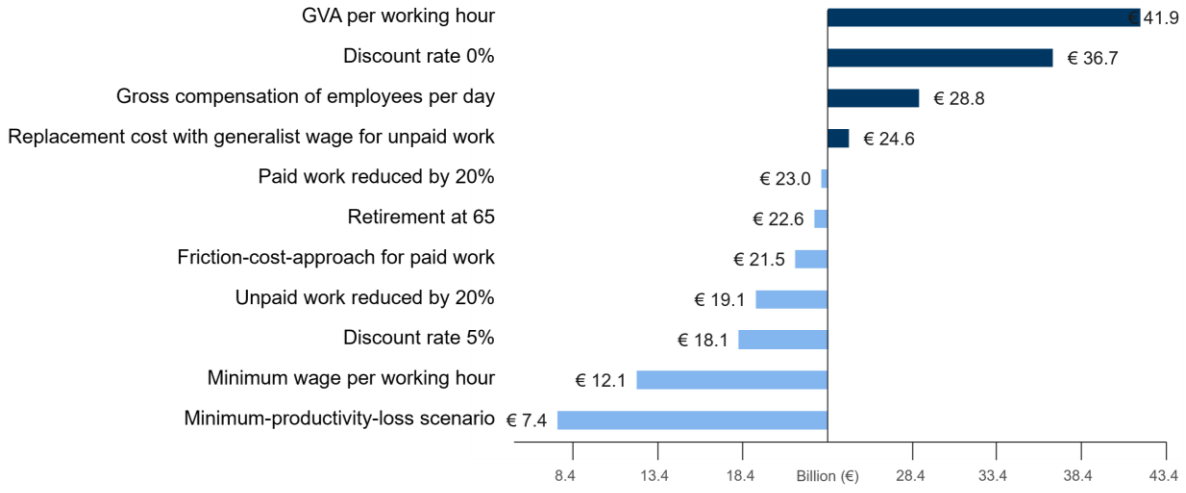
Figure 8: Socioeconomic burden in monetary terms in alternative scenarios compared to the base case estimate

Socioeconomic burden in monetary terms – Estimate for hospitalizations and rehabilitation cases



Base case: 1.1 billion EUR

Socioeconomic burden in monetary terms – Estimate for death cases (YLL)



Base case: 23.4 billion EUR

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis), Eurostat, and Institut für Arbeitsmarkt- und Berufsforschung (IAB), and other sources (see section 2.1). Rounded numbers.

2.3 Interim conclusion and limitations

In this study, we quantified the health and socioeconomic burden of ASCVD diagnoses, namely ischemic heart diseases, cerebral infarction and sequelae, and atherosclerosis, in the adult German population for 2019. Cases among children and adolescent were not considered. This is relevant to keep in mind when comparing our results to studies that include the whole population. However, no large variations in mortality rates, hospitalizations, and rehabilitation are to be expected, since ASCVDs rarely occur at a younger age.

We considered disease events attributed to ten diagnoses separately for the 16 German federal states and accounted for losses in paid and unpaid work activities. To date, no studies were identified that quantify and monetarize both types of productivity loss due to ASCVD in Germany. Because ASCVD-related events disproportionally affect older age groups, focusing only on paid work would have ignored an important aspect of the socioeconomic burden. Thus, potentially underestimating the economic and societal benefits that disease prevention can have.

The results of must be interpreted in acknowledgment of several limitations. First, our estimate of the health and socioeconomic burden is based on inpatient hospitalizations, rehabilitation, and death cases as relevant health outcomes. This approach allowed us to use highly reliable data, namely hospital diagnosis and rehabilitation facilities records, and cause of death statistics, as the model foundation. These data sources also offered a high degree of age and gender specific stratification at federal state level, which allowed the consideration of regional differences. However, the chosen health outcomes only represent part of the actual ASCVD burden. Hospitalization, rehabilitation, and death are severe disease events that do not allow statements on outpatient care. That is, patients with less sever disease forms or patients that have been diagnosed in the past and are now treated by a general practitioner or specialist outside the hospital. Beyond the included health outcomes, the burden of ASCVDs extends to permanent functional impairment and reduced quality of life. Therefore, our estimates may be interpreted as the core of hard evidence concerning the disease burden.

Other main limitations relate to the applied assumptions and input parameters. Data on socioeconomic input parameters for older age groups are relatively scarce and often limited in terms of a catch-all category for ages above a certain age. We assumed that data for a catch-all age category is similarly valid for all covered age groups. Therefore, we did not account for a potential bias for age groups 80 and older, who represent a substantial share of those suffering an ASCVD-related event. An equally important model assumption relates to the concept of YLL. We used the respective German population estimates on average life expectancy at a certain age to quantify the YLL due to ASCVDs. It is however plausible that a greater than average share of those dying due to an ASCVD diagnoses suffered from a pre-existing condition. In general, assumptions become increasingly unreliable for longer time horizons into the future. The COVID-19 pandemic introduces an additional degree of uncertainty to relevant health and socioeconomic parameters. Like the previous point, this may relate to the estimated life expectancy at a certain age. However, it may also relate to assumptions about the counterfactual lives of deceased individuals and their productivity at different ages, which were necessary to calculate the productivity loss associated with premature mortality.

3 The role of the COVID-19 pandemic for CVDs

Since the beginning of the year 2020, Germany among many countries in the world was confronted with the severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) and the concomitant COVID-19 pandemic. Due to the novelty of the disease, questions concerning comorbidities, risk factors and long-term effects resulting from a SARS-CoV-2 infection arose. Similarly, the pandemic situation has changed the daily lives of many people, as countries implemented stay-at-home orders, asked people to work from home, reduce their social contacts and more. We conducted a literature review aimed to answer how the COVID-19 pandemic could affect CVD risk in general and the risk for more severe disease outcomes in people with a pre-existing CVD in Germany. We further divided our research question in sub-questions to account for different mechanisms that might be at play.

Our analysis shows heterogenous results in the three areas under consideration, that is behavioral changes in lifestyle risk factors stemming from the new pandemic situation, healthcare seeking and provision, and post-acute implications of a SARS-CoV-2 infection. Our analysis was based on peer-reviewed journal articles, limiting the evidence to draw from to the early stages of the pandemic. With the progress of the ongoing pandemic, more data will be available in the future and long-term trends may be observed when the time horizon under consideration will increase.

The chapter is structured in the following way: First, we explain the hypothetical relationship between COVID-19 and CVDs and state the research questions that were developed for our analysis. In the next step, we describe the method of our literature review and elaborate on our inclusion and exclusion criteria. In the third subchapter we summarize the results. Lastly, we discuss what can be inferred from our analysis and the limitations of our literature review are debated.

3.1 Hypothetical relationship between COVID-19 and CVDs and resulting research questions

Early evidence suggests that the COVID-19 pandemic could lead to an increase in CVD risk factors, both via SARS-CoV-2 infection and behavioral changes, and increase the risk for severe CVD outcomes in patients with a pre-existing condition (Mattioli et al., 2020; Woods et al., 2020; Zeymer et al., 2021; Saleh et al., 2020; Böhm et al., 2020). Therefore, our literature search aims at answering the following research question:

What are the (future) effects of the COVID-19 pandemic on CVD risk and on the risk for more severe CVD outcomes in Germany?

In a preliminary literature screening, we identified behavioral changes due to the pandemic situation and being infected with COVID-19 as the most relevant possible connections between the COVID-19 pandemic and CVDs. The assumed effect mechanisms in each case are shown in Figure 9 and Figure 10.

Figure 9: Possible effect mechanisms of the COVID-19 pandemic on CVDs

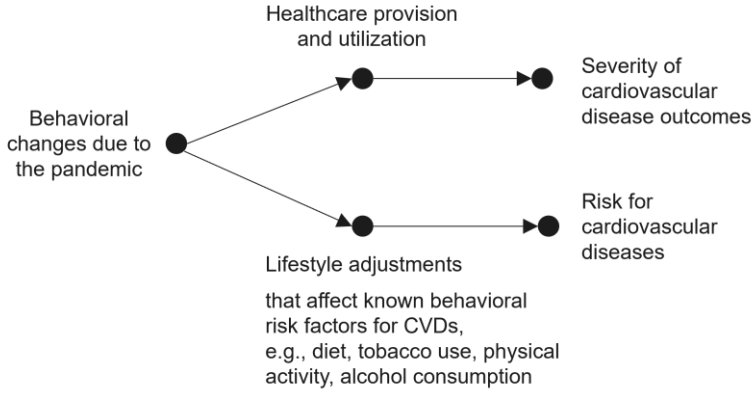
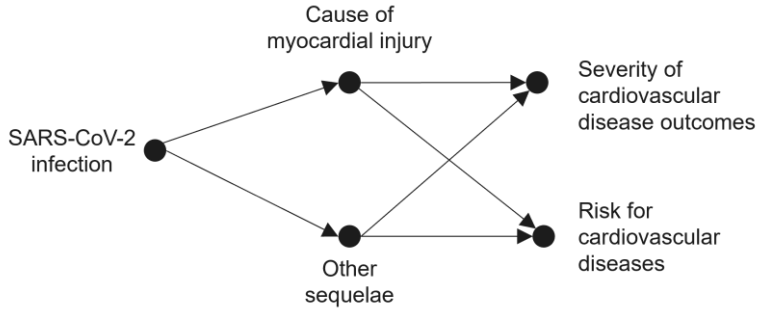


Figure 10. Possible effect mechanisms of a SARS-CoV-2 infection on CVDs



On this basis, we formulate the following four sub-questions to guide the literature search:

a) What effect does the COVID-19 pandemic situation have on treatment decisions of patients and on healthcare provision?

b) What effect does the COVID-19 pandemic situation have on people's lifestyle regarding known and preventable behavioral risk factors for CVDs?

c) What effect does a SARS-CoV-2 infection (post-acute) have on risk for CVDs?

d) What effect does a SARS-CoV-2 infection (post-acute) have on the risk for severe CVD outcomes in patients with a pre-existing CVD?

3.2 Methods description of literature review

While the literature review on COVID-19 and CVDs is not a stand-alone study, a systematic and comprehensible approach is still necessary. Therefore, we apply a mixed approach of following the general principles of a systematic literature review but adapting procedures to suit the scope and timeline of this study. This approach may in some instances resemble a scoping review (Munn et al., 2018). However, while the evidence on COVID-19 is still emerging and growing, we aim to consider the quality of the existing evidence, its informative value and generalizability. These factors thus require a systematic literature approach (Munn et al., 2018).

3.2.1 Search strategy and selection criteria

Building on keywords used in the relevant articles from the preliminary literature screening and adding terms from the Medical Subject Headings (MeSH) vocabulary, we set up a list of search keywords. We assigned keywords to the following main categories:

(1) COVID-19 (including both the infection and the pandemic situation)
(2) Cardiovascular disease
(3) Healthcare provision and utilization (treatment decisions) (indirect link)
(4) Lifestyle changes as a risk factor for cardiovascular diseases (indirect link)
(5) Geographic location

Keywords within each main category and the search strategy were tested in a trial run of the literature search and adapted subsequently. The final list of keywords can be found in the appendix (Annex 4).

PubMed database was searched using a combination of keywords from the main categories for each sub-question: Each keyword from a main category was combined with each keyword from the other main categories at a time, i.e., keywords within a category were connected via the Boolean operator OR, while the main categories were connected via the operator AND. Different word spellings and singular/plural forms were accounted for. For example, to answer sub-question a) "What effect does the COVID-19 pandemic situation have on treatment decisions of patients and healthcare provision?" we ran a search query on the keywords within main categories 1, 2, 3, and 5:

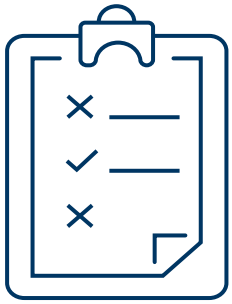
"COVID-19 AND Cardiovascular disease AND Healthcare AND Geographic location (Germany)"

The literature search in PubMed was performed on August 31, 2021. The query translates can be found in the appendix (Annex). The exported citation records were used in a second step, namely the title and abstract screening. For this step, each PubMed record was independently screened by two reviewers. Both reviewers collected information that could be gathered from the title and abstract of an article. Various information was obtained in this process with the aim of deciding whether the article meets the inclusion criteria or should be excluded (Annex 7).

The inclusion and exclusion criteria were defined before the retrieval of the abstracts. They were continuously refined and amended during the title and abstract screening and later during the full-text retrieval.

Inclusion criteria

- Date: Published between Jan 01, 2020, and Aug 31, 2021
- Language: English and German
- Peer-reviewed journal article
- Geographic location: Germany (only applied to articles on healthcare and lifestyle aspects)
- Study population: Adults (18 years and older)
- COVID-19 as independent or explanatory variable



Exclusion criteria

- Study population is very specific and may not be used to infer or generalize information for the German population (e.g., professional athletes)
- Article type: Position paper /opinion, commentary, treatment guidelines, study protocols, and conference proceedings
- Case reports or case studies with sample size of n <100 patients (only applied to articles on healthcare and lifestyle aspects)

- Dependent variable or reported outcome is mental health /stress, or not a known risk factor for CVD
- COVID-19 infection as dependent variable
- Study design does not allow pre/post-COVID-19 pandemic comparison (no inference on causality possible)
- Relevant limitations in article quality (e.g., article does not describe method of data collection, sample shows relevant bias)

Differences in Google Scholar search and abbreviated abstract pre-screening

We used Google Scholar as an additional database and search engine to allow for peer-reviewed articles not listed in PubMed and for grey literature with a high relevance for Germany. When performing a systematic literature search via Google Scholar, however, there are specific features to be aware of: The search string is limited to approximately 220 characters. Thus, the number of keywords is limited. As a result, we used by far less keywords in the Google Scholar search compared to the search in PubMed and did not check for different spellings. The underlying search algorithm is not publicly available. For this reason, the list of keywords and their combination were determined via trial and error. Furthermore, there are only few advanced search settings, generating many duplicate records and unsuitable search results. Due to these limitations, we decided to use Google Scholar primarily as a supplemental source for German-language articles. The search strings with Boolean operators differ from the previously in PubMed used combinations (Annex 8, Annex 9). Because of the German-language keywords, we used ”any language“ as a search setting.

Due to the large number of hits and rapidly decreasing relevance for our research questions, two reviewers performed an abbreviated title and abstract pre-screening of the first three search pages (equivalent to 60 records). In a second step, articles identified as relevant were categorized in Google libraries according to the search queries performed on September 14, 2021, and October 1, 2021, for the four sub-questions a), b), c), and d). The searches are named by question and date. It should be noted that due to restrictions in search string length, two different queries were performed for question b). The exported citations records were then compared with those obtained via PubMed search and duplicates removed. The title and abstract screening then followed the same procedure as for PubMed records.

3.2.2 Full-text retrieval and data extraction

After the title and abstract screening, records that were assessed relevant for inclusion in the full-text retrieval obtained via PubMed and Google Scholar were pooled. At this stage of the review, every full-text article was assessed by one reviewer, who collected detailed information on the article content (Table 5). Inferences about future trends were of special interest to our research question. Therefore, information on the time horizon and timing of effects was retrieved if available. Since generalizability of study results for the German population is an important condition for deriving future trends, we appraised this characteristic of included studies during our full-text review. We discussed ambiguities within the team at several points during the full-text retrieval.

It became clear during earlier stages of the review process, that a differentiation between articles answering research questions c) and d) was neither applicable nor useful. It was therefore discontinued at this stage of the review.

Table 5: Data collected during the full-text retrieval

Category	Specification
Inclusion in full-text analysis	Does this article provide information to answer one or more of our research questions?
Exclusion criterion	If article is excluded, which is the main reason /criterion
Generalizability of results /informative value	
Study type or method	e.g., clinical study, observational study, telephone survey
Study population	Describe main characteristics
No. of patients /participants observed	Sample size
Exact disease (if applicable)	e.g., ischemic stroke
Observation period: Date	Month and year, or calendar week and year
Observation period: Phase of the COVID-19 pandemic	Classification of pandemic phases in Germany according to Robert Koch Institute (Schilling et al., 2021; Tolksdorf et al., 2021)
Key results	Briefly describe key result(s) of the article (including effect size if applicable)
Timing of mechanism or effect	Does this article provide information on observed or assumed time between cause and effect? (e.g., instantaneously, delayed)
Long-term trend	What kind of long-time trend can be inferred (if any)?
Characteristics of the study indicating good quality or high informative value	Which characteristics positively distinguish the study? (e.g., balanced sample, large sample size)
Limitations of the study	Which characteristics limit the quality of the evidence? (e.g., convenience sample, recall bias, non-response bias)
Country	Articles on COVID-19 infection could refer to a country other than Germany
Outcomes	We collect information for each relevant outcome studied in an article: Hospital /emergency room admission rates Healthcare utilization, ambulatory care Survival rates /in-hospital mortality Length of hospital stay Hospital workflow and delay of treatment 30-day rate of readmissions Functional outcome at discharge Operations /procedures Changes in severity of events Myocardial injury CVD mortality in general Comorbidities Bodyweight /BMI changes Physical activity levels Alcohol consumption levels Tobacco consumption levels Eating behavior (foods and drinks) Report key result or effect estimate
At-risk groups	Characterize at-risk groups (if applicable), for example, persons that showed an increased risk for negative behavioral changes

3.3 Results of the literature review

3.3.1 Study characteristics

In total, 423 potentially suitable article records were identified in the electronic databases. After identifying and removing duplicates, 391 abstracts were screened. Altogether 99 articles met the eligibility criteria for full-text retrieval and were assessed in full. Finally, 43 articles from our database searches were included in this analysis. An additional three articles were identified as relevant through reference screening (Figure 11).

Of the final 46 articles, 30 articles covered aspects of healthcare utilization and provision, 12 covered aspects of lifestyle changes in CVD risk factors, and five articles covered CVD-related post-acute implications of a SARS-CoV-2 infection. In some cases, the same article covered multiple aspects.

Fifteen of the included articles were published in 2020 and 31 in the year 2021. Forty-one were original research articles, three overview articles, one literature review, one was a meta-analysis, and one was classified as grey literature.

The included original research articles represented different empirical study designs and were based on different types of data. Twelve of all included publications were surveys, 21 were based on claims data or other administrative records, four were single center studies, four were based on data from a disease registry.

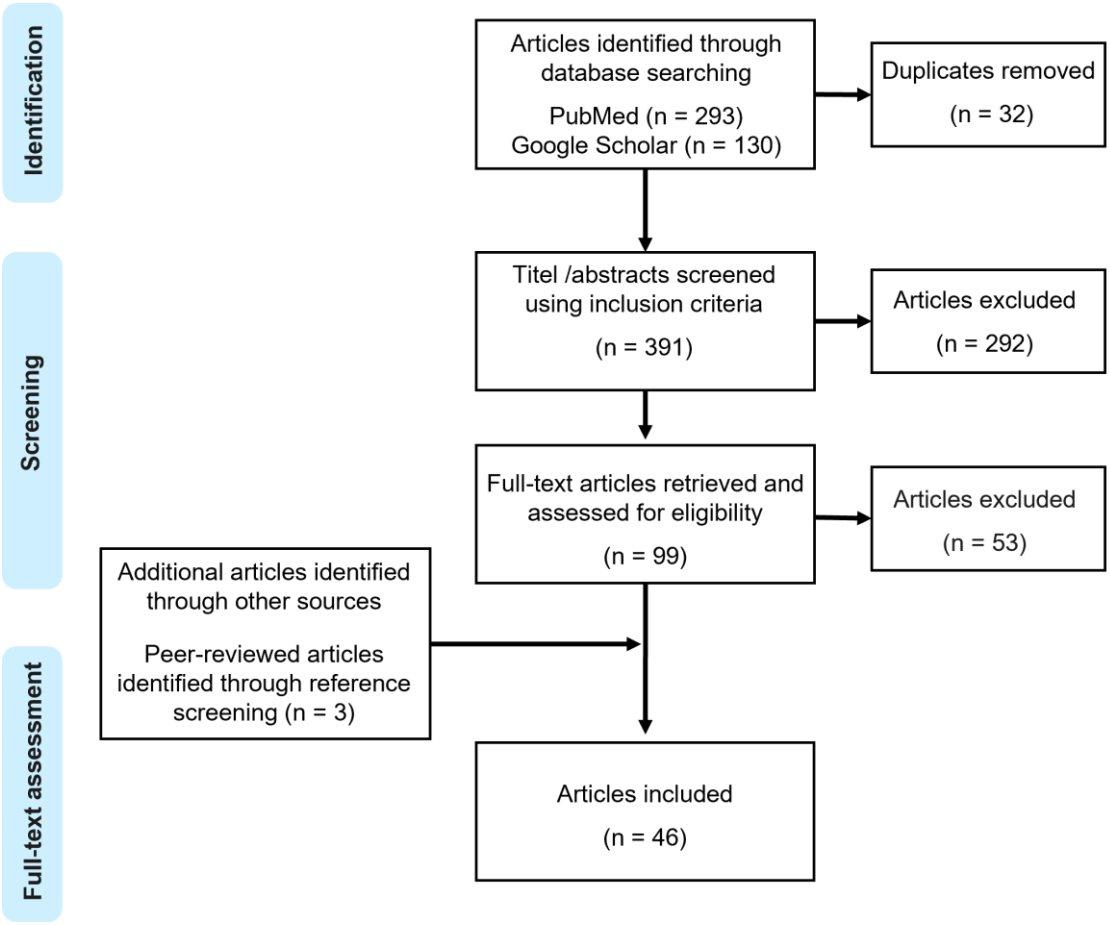
The German Robert Koch Institute published a retrospective classification of the pandemic phases in Germany (Schilling et al., 2021; Tolksdorf et al., 2021). These phases correspond approximately to a first wave from March to mid-May 2020 (phase 1), a summer period from mid-May to September 2020, a second wave from October 2020 to February 2021 (phase 3), and a third wave from March to June 2021 (phase 4). Of the final included empirical studies, 40 covered (part of) the first wave in Germany. Of those, 18 studies also covered phase 2, and seven studies covered (part of) phase 3. Phase 4 was not observed in the included articles.

Article characteristics differed greatly between articles that cover different aspects of the relationship between the COVID-19 pandemic and CVDs. For this reason, we decided to approach the full-text analysis as well as presentation of results differently for each sub-question. As can be seen by the various outcomes covered in the results section of this chapter, the reviewed articles answered different facets of our sub- questions.

3.3.2 Results concerning healthcare provision and utilization

Thirty articles were included in the full-text analysis to answer question a) “What effect does the COVID-19 pandemic situation have on treatment decisions of patients and healthcare provision?”. Each article covered at least one of the following aspects: patient characteristics of treated patients, comorbidities of patients, CVD mortality in general, 30-day rate of readmissions, functional outcome at discharge, changes in severity of disease, hospital workflow and delay of treatment, other healthcare utilization and ambulatory care, operations and procedures, length of hospital stay, survival rates /in-hospital mortality, and hospital admission rates. The latter was found to be the dominating outcome among the 30 included articles, with 22 of the articles covering this aspect. In the following, we provide a short overview over the information extracted from the publications in our literature review. The overview includes only selected articles and the results that were drawn from them specifically, as article quality and generalizability of results varied greatly between articles. A list of all articles covering each aspect can be found in the appendix (Annex 10).

Figure 11: Flow diagram on search results and review process



No difference in patient characteristics

In a nationwide representative study, Vollmuth et al. (2021) analyzed the impact of the COVID-19 pandemic on telemedical stroke consultation in Germany between March 24, 2020 and April 19, 2020 ("first lockdown") and found no difference in stroke consultations in terms of patient characteristics such as patients' gender, age, or stroke severity when comparing this time frame with the values from 2018 to 2019.

Similarly, the study by Wienbergen et al. (2021) found no significant difference regarding gender, age and patients' medical history when comparing patients treated for acute ST-elevation myocardial infarction (STEMI) when comparing patient characteristics between 2019 and 2020.

Significant increase in comorbidities

In a retrospective, observational study analyzing administrative data of 67 hospitals in Germany, König et al. (2020) found that among patients with the main diagnosis of heart failure the patients hospitalized in the time period March 13 to May 21, 2020 had significantly more comorbidities compared both to the same year control and the previous year control. Patients with a proven COVID-19 infection were excluded from this analysis.

Heterogeneous result for 30-day rate of readmissions and urgent hospital visits

While König et al. (2020) observed an increase in the 30-day rates of urgent readmissions and urgent hospital visits for patients with the main diagnosis of heart failure (at discharge) compared to the same year control, they did not detect a significant change compared to the previous year control.

Increase in disease severity

In a retrospective, observational study analyzing administrative data of 67 hospitals in Germany, König et al. (2020) found that among patients hospitalized with the main diagnosis of heart failure during the time period March 13 to May 21, 2020 case severity increased significantly in comparison to the same year control and the previous year control respectively. Furthermore, intensive care treatment utilization significantly increased compared to both control groups respectively.

Similarly, Mostert et al. (2021) found an increase in disease severity during the observation period from March to May 2020, while using a different severity measure than König et al. (2020). The authors noted an increase in disease severity of 3.1% for heart failure and 7.2% for chronic ischemic heart disease, comparing to 2019, respectively. Furthermore, for heart failure there was a 2.5% increase in October 2020 compared to 2019.

Adding to this, the analysis by Wienbergen et al. (2021) found a significant drop in the proportion of patients who were admitted without any clinical signs of heart failure when comparing the figures from 2020 with those of 2006 to 2019. Their analysis further found an increased rate of in-hospital cardiac arrests in the observation period compared to the 2006 to 2019 control.

Heterogeneous results in terms of hospital workflow and delay of treatment

In their nationwide cohort study, Richter et al. (2021a) did not detect changes in treatment quality between the observation period March 16 to May 15, 2020 and the two control periods (pre-pandemic control period from January 16 to March 15, 2020 and previous year control period from March 16 to May 15, 2019). The authors conclude that AIS patients received the same high treatment quality as before the pandemic.

Similarly, Scholz et al. (2020) did not detect a statistically significant change in medical help seeking behavior by symptomatic STEMI patients. Further, the authors find no statistically significant delay in the mean contact-to-door time when comparing March 2020 to the March months from 2017 to 2019. Therefore, they conclude that despite COVID-19 precautions, there were no clinically relevant delays. In support of this, there was no statistically significant change in the mean door-to-balloon time during the observation period when comparing to the controls. The results remained stable in several statistical models with the only exception being a small but significant increase in the average time from arrival at the catheterization laboratory to vessel puncture detected in univariate analysis. As pointed out by the authors, only clinics participating in the "ongoing, multicenter, prospective Feedback Intervention and Treatment Times in ST-Elevation Myocardial Infarction (FITT-STEMI) study" were considered, limiting the generalizability of the result.

Decrease in other healthcare utilization and ambulatory care

Damerow et al. (2020) explain that healthcare utilization is generally subject to seasonal changes. Their cross-sectional study of people living in Germany found a statistically significant reduction in healthcare utilization for general practitioners and specialist care during calendar weeks 15 to 26 of 2020 compared to the 2019 control period. Similarly, for both telemedical consultations and telemedical stroke consultations a significant decline during the first wave of the pandemic was observed by Vollmuth et al. (2021). However, for teleconsultations the authors did find a partial rebound after the relaxation of COVID-19-related containment measures in Germany.

Operations and procedures

In their nationwide cohort study Richter et al. (2021a) compared the use of time-dependent procedures such as intravenous thrombolysis (IVT) and mechanical thrombectomy (MT) between the observation period during the first wave of the pandemic (March 16 to May 15, 2020) and two control periods in Germany. There was a pre-pandemic (January 16 to March 15, 2020) and a historical control (March 16 to May 15, 2019).The main diagnoses under consideration for the hospitalized patients were acute ischemic stroke (AIS), transient ischemic attack (TIA), or intracerebral hemorrhage (ICH) While the IVT rate in patients with AIS did not differ statistically significant between pandemic and the two control periods, a significantly higher MT rate during the pandemic compared to the historical control was reported.

In a further analysis of use of treatment procedures for various time periods of 2020, the findings by Richter et al. (2021b) differed somewhat: On the one hand, IVT rates were significantly lower between October 1 and December 31, 2020 when compared to the previous-year time period. On the other hand, similarly to the beforementioned findings

by Richter et al. (2021a), the authors found the MT rate in 2020 to be consistently higher than the one in 2019. The highest difference in MT rates was observed during the first wave of the pandemic. The authors did not detect statistically significant differences in IVT and MT rates between AIS patients with or without COVID-19.

The analysis carried out by König et al. (2021) found a statistically significant reduction of cardiac procedures in their observation period from March 13 to September 10, 2020 in comparison to the previous year control.

Further, Vollmuth et al. (2021) analyzed the trends in mean daily rate of recommendations for IVT and endovascular treatment as well as recommendation rates for IS patients. They observed a statistically significant decrease in mean daily recommendations rate to perform both for endovascular treatment and IVT during the first lockdown period (March 16 to April 30, 2020), compared to previous months control (January 1 to March 15, 2020). The change in the rate of recommendations to perform either IVT or endovascular treatment in IS patient was non-significant.

Significant decrease in hospital stay length

Across various studies analyzing different time periods within 2020 and varying CVD diagnoses respectively, the reviewed studies found a significant decrease in the length of hospital stays. The degree of the decrease differed between the various studies (Bollmann et al., 2020; Bollmann, Hohenstein, et al., 2021; König et al., 2020; Mostert et al., 2021; Ueberham et al., 2021).

The very comprehensive study carried out by Mostert et al. (2021) found that the length of hospital stay was shorter for urgent conditions such as MI, stroke, and TIA. However, this was not true for mostly postponable conditions such as heart failure and chronic ischemic heart disease during March to May 2020 when case severity increased.

Mixed results for survival rates /in-hospital mortality

Most of the reviewed articles found an increase in in-hospital mortality during the COVID-19 pandemic compared to same-year or previous year controls. This was true for different kinds of cardiovascular diseases or events.

An increase in in-hospital mortality of 20% for patients admitted for heart failure observed by Bollmann et al. (2020) during the observation period from March 13 to April 30, 2020 compared to a same year control and a previous year control was statistically significant under univariate analysis. In another study, analyzing data for the period from March 13 to December 12, 2020, Bollmann, Hohenstein et al. (2021) also found a significant increase in in-hospital mortality in CVD cases compared to the control period (same weeks in 2019). Adding to this, König et al. (2020) also observed an in-hospital mortality for acute heart failure patients that was significantly higher during the study period compared to both the same year control group and the previous year control group.

While Richter et al. (2021a) studied patients with AIS and ICH, the observed trend remained the same. For both types of patients, the authors detected a significantly higher in-hospital mortality. Further, in a similar analysis, Richter et al. (2021b) also found that the proportion of AIS patients who died during the hospital stay was significantly higher during the first wave in 2020 as compared to the corresponding period in 2019 (8.0% vs. 7.5%, $p = 0.021$).

However, an analysis by Behrendt et al. (2021) found mixed results: On the one hand, the authors detected a significantly increased in-hospital mortality for patients with acute stroke during the COVID-19 pandemic when compared to 2017 to 2019. On the other hand, changes in the in-hospital mortality for STEMI, NSTEMI, acute limb ischemia (ALI), aortic rupture, and transient ischemic attack (TIA) proved to be statistically non-significant. Similar results were found by Seiffert et al. (2020): While in-hospital mortality was significantly higher for patients admitted for stroke, it was not significantly different among patients admitted for other cardiovascular or cerebrovascular emergencies during the COVID-19 pandemic compared to pre-COVID-19 eras.

Mixed results of impact of concurrent COVID-19 infection on in-hospital mortality

In their nationwide cross-sectional study, Richter et al. (2021b) found that acute ischemic stroke (AIS) patients with concurrent COVID-19 showed a significantly higher in-hospital mortality rate during the observation periods March through May 2020, and October through December 2020, compared to AIS patients without COVID-19 infection. Furthermore, during the first and second waves of the pandemic intravenous thrombolysis (IVT) was done frequently in SARS-CoV-2 positively tested AIS patients. However, IVT application did not differ significantly between AIS patient with and without concurrent COVID-19.

Similarly, Behrendt et al. (2021) found a statistically significant higher in-hospital mortality for patients with a concurrent COVID-19 infection for acute stroke, ALI, and TIA. For SARS-CoV-2 positively tested patients suffering aortic rupture, STEMI, and NSTEMI, in-hospital mortality did not statistically significant differ from non-infected patients.

Decrease in hospital admission rates

Most of the articles in our review focused on changes in hospital admission rates due to the COVID-19 pandemic. Similarly to the aforementioned decrease in hospital stay length, a remarkable homogeneity in the trend of hospital admission rates can be drawn from the reviewed literature. Across different kinds of CVD diagnoses, time periods, and types of studies, authors report a decrease in hospital admission rates in comparison to same year or previous year controls, respectively (Bollmann et al., 2020), (Bollmann, Hohenstein, et al., 2021), (Bollmann, Pellissier, et al., 2021), (Günster et al., 2020), (König et al., 2020) (König et al., 2021) (Mostert et al., 2021) (Rattka et al., 2021) (Richter et al., 2021a) (Seiffert et al., 2020) (Ueberham et al., 2021) (Vacanti et al., 2020). The focus of these studies was mainly on the situation during the first pandemic wave in Germany. Decreasing admission rates were for example observed for heart failure emergency admissions (Bollmann et al., 2020) or myocardial infarction (Rattka et al., 2021). One study (Rattka et al., 2021) found that for an observation period after the first wave, hospital admission rates did show a rebound. In their comprehensive study, Mostert et al. (2021) observed a decrease for both urgent and mostly postponable conditions (heart failure and chronic ischemic heart disease) during the first wave in Germany.

Summing up the results concerning healthcare provision and utilization, on the one hand, some developments seem to be following a homogeneous trend, such as the decrease in hospital stay length and hospital admission rates. On the other hand, other developments differ between studies, e.g., in-hospital mortality and delay of treatment. Various aspects were addressed under the research question, representing the broad spectrum of health care provision and utilization.

3.3.3 Behavioral changes in lifestyle risk factors

Twelve articles included in the full-text analysis covered aspects on question b) “What effect does the COVID-19 pandemic situation have on people’s lifestyle regarding known and preventable behavioral risk factors for CVDs?”. Physical activity was the most studied outcome (10 articles). Other outcomes were weight gain, alcohol consumption, tobacco consumption, and food intake. In the following, we provide a short overview on the found evidence on each outcome. A list of all articles covering each aspect can be found in the appendix (Annex 11).

Significant weight gain

Between April and August 2020, a significant weight gain of approximately one kilogram and half a unit of body mass index (BMI) was measured in Germany compared to the previous year (Damerow et al., 2020).

Mixed results on reduced physical activity

In a cross-sectional survey in March 2020, men on average reported doing 1.4 hours less physical exercise per week, women on average reported 0.5 hours less physical exercise compared to data from October 2019 (Engels et al., 2021). The reported reduction in physical activity was statistically significant for both groups.

In contrast, the results of another survey showed no significant decrease in physical activity in April 2020 compared with data from 2014 and 2015. However, individuals with children, lower education, and fewer personal resources, showed an increased risk of not meeting the WHO recommendation of 2.5 hours of physical activity per week during the first wave of the pandemic in Germany (Maertl et al., 2021).

Heterogeneous results were shown in an analysis by Mutz & Gerke (2021): Of the survey respondents, 31% reported a decrease in physical activity, while 27% did not report any change in their physical activity level, and 6% did more exercise. The remaining 36% of respondents were not physically active either during or before the pandemic. With increasing age, respondents were more likely to report exercising less during the pandemic.

Another study reported a significant increase in screen time and snack time, while physical activity decreased (Mata et al., 2021). However, the frequency of snacking and physical activity returned to baseline within two months and only screen time continued to increase (Mata et al., 2021).

At least one behavioral change with potentially negative health consequences

The analysis carried out by Koopmann, Müller, et al. (2021) found that 58.5% of survey respondents reported that they had reduced their physical activity and/or increased their food intake during the first pandemic wave in Germany. The authors classified 18.8% of respondents as a high-risk group. These reported being less physically active while eating more. In the observed sample, these individuals tended to be women, younger than 65 years, and experienced higher levels of subjective stress.

Mixed results regarding alcohol consumption

In a European study, German respondents reported a slight decrease in overall alcohol consumption in the second quarter of 2020 (Kilian et al., 2021; Manthey et al., 2020). Self-reported frequency of alcohol consumption on average slightly increased, while the amount of alcohol consumed remained the same, and binge drinking decreased significantly (Koopmann, Georgiadou, et al., 2021).

Heterogeneous results were shown in another survey study: 35.5% of respondents reported drinking more, 21.3% less, and 43% of the respondents did not change their alcohol consumption behavior (Koopmann, Georgiadou, et al., 2021). People whose jobs or finances had been negatively affected by the COVID-19 pandemic, those who experienced high subjective stress, those who drank alcohol more than once a week, or who had an overall high alcohol consumption, were more likely to report a further increase in their alcohol consumption (Georgiadou et al., 2020; Koopmann, Georgiadou, et al., 2021; Manthey et al., 2020).

Mixed results regarding tobacco use

While one survey found no causal differences in tobacco use attributable to the pandemic (Damerow et al., 2020), 42.7% (Georgiadou et al., 2020) and 45.8% (Koopmann, Georgiadou, et al., 2021) of smokers in two other studies reported increased tobacco use during the first pandemic wave in Germany. However, 9.0% of smokers also reported smoking less, 9.9% quit smoking, while 4.0% started smoking (Koopmann, Georgiadou, et al., 2021). Individuals with a higher perceived stress level showed an increased risk of increasing their tobacco use (Koopmann, Georgiadou, et al., 2021).

3.3.4 Post-acute implications of a COVID-19 infection

Finally, five articles were included on the post-acute implications of a COVID-19 infection for CVD risk and disease outcomes in patients with a pre-existing CVD (questions c), d)).

The full-text retrieval revealed that the causal direction of the relationship between an acute COVID-19 infection and CVDs often remains unclear and the definition of sequelae or comorbidities difficult to differentiate. The included articles directly refer (if mostly only in a minimal way) to post-acute sequelae of COVID-19. Two articles are overviews, one a literature review, two articles present original research with one study (Al-Aly et al., 2021) being conducted in the USA.

Cardiovascular involvement

In their overview article, Jakstaite et al. (2021) summarize the still growing evidence of myocardial injury and cardiovascular involvement in acute COVID- 19 patients. Against this background, they point to evidence for long-term cardiovascular complications found in the cardiovascular magnetic resonance (CMR) study by Puntmann et al. (2020). Therein, based on data from a German COVID-19 registry CMR imaging, cardiac blood markers, and demographic characteristics of 100 recently recovered COVID-19 patients between April and June 2020 were analyzed. Cardiac involvement was found in 78% of patients and ongoing myocardial inflammation in 60%. Myocardial inflammation did not correlate with preexisting conditions and time interval since acute COVID-19 infection (Puntmann et al., 2020).

Neurological sequelae

While the overview article, an update from neurological view, by Simon et al. (2021) provides no evidence on post-acute COVID-19 sequelae in terms of cerebrovascular events, it points to persisting neurological symptoms (e.g., fatigue, sleeping disorder, dysosmia, headache) after COVID-19 infection. These symptoms have been linked to various organic changes the significance of which remains yet to be understood.

Atherosclerosis

In a literature review conducted in September, 2020, Grzegorowska & Lorkowski (2020) come to the conclusions that a correlation between inflammation in COVID-19 patients and atherosclerosis is likely. However, the authors find no direct evidence for an influence of COVID-19 infection on atherosclerotic plaque progression.

Post-acute COVID-19 sequelae

Based on the healthcare database of the US Department of Veterans Affairs, Al-Aly et al. (2021) conducted a high-dimensional characterization of post-acute sequelae of COVID-19 considering a broad range of health conditions (incident diagnoses), medication use, and laboratory abnormalities. The analysis included both patients that were and were not hospitalized with a COVID-19 infection who survived at least 30 days after diagnosis over a time horizon of 6-months. Individuals who were hospitalized with seasonal influenza were considered as controls for hospitalized COVID-19 patients, while COVID-19 patients who were not hospitalized were compared to controls without COVID-19 infection. The authors find an excess burden (higher incidence) of metabolic disorders (disorders of lipid metabolism, diabetes mellitus, obesity, elevated LDL-C), and of cardiovascular conditions (hypertension, cardiac dysrhythmias, circulatory signs and symptoms, coronary atherosclerosis, and heart failure) in COVID-19 patients who were not hospitalized. An excess burden in cardiovascular disorders was also observed in patients who were hospitalized for COVID-19 compared to influenza controls.

3.4 Interim conclusion and limitations

The outcomes studied in our literature review were wide ranged, as one can tell by the various categories for which information was collected in the literature review. This is not only true for the outcomes, but also for the included CVD diagnoses. The diversity of the retrieved information is also reflected in the different time horizons under observation, by the various population groups included, and by the different methods that were applied to obtain results. In short, our results show that the impact of the COVID-19 pandemic was multifaceted.

The results on the pandemics impact on healthcare can be seen from two perspectives. On the one hand, there is the patient perspective, where patients changing their medical help seeking behavior could impede their later health outcomes. On the other hand, there is the healthcare provider perspective, where it is important to know, whether the pandemic affected the timely availability of treatment and factors such as hospital stay length. As the results from our literature review show, a decrease in hospital admission rates could be detected. Whether this decrease effectively led to a change in patients' health outcomes, not only in the short-term but also in the long-term, would need to be investigated by further research. The increase in disease severity, that some studies detected, may reflect a change in the medical help seeking behavior, as cardiovascular events such as a stroke or MI would need to be treated in a timely manner. At the same time, other studies showed no difference in medical help seeking behavior for symptomatic STEMI patients. Thus, demonstrating that patients suffering from an acute CV event that requires immediate medical attention do not likely delay opting for treatment.

Taking the angle of healthcare provision, door-to-balloon-time and symptom-to-door-time did not show statistically significant changes between the observation and control periods, therefore providing patients with timely access to healthcare. The observed decrease in hospital stay length could be due to both provider or patient behavior changes. It is unclear, whether this decrease is solely the result of an early discharge policy implemented by hospitals, or whether patients wished to leave the hospital due to fear of a COVID-19 infection or other reasons. Whether this influenced patients' health outcomes for the different CVD outcomes needs further research.

The results concerning behavioral changes in lifestyle risk factors were characterized by heterogeneity in the observed outcomes as well as great heterogeneity in terms of study design, methods, and study population. While weight gain could be detected across the German population, the results on other lifestyle aspects did not show as homogeneous. Even for the clearly observed weight gain, we cannot draw conclusions from our review between the magnitude of change in behavior and changes in CVD risk. For example, body weight only is one factor among others, such as smoking and reduced physical activity. The individual risk for developing a CVD may improve or worsen by isolated behavioral changes.

Overall, the various dimensions covered in our systematic review paint a broad picture of possible impacts on CVD risk and CVD outcomes. At the same time, this makes it difficult to draw a conclusion as each aspect answers the research question from a different angle. Furthermore, even within an outcome category, the comparability of studies is limited due to the different study designs, methods applied, and study populations under review. Therefore, conclusions can only be drawn while considering the specifications of each individual study.

Different kinds of limitations apply to the results of our literature review: Those limitations that relate to characteristics of the reviewed literature and those that relate to the review process and chosen methods.

First, due to the exclusion of pre-print publications, the period covered in included articles is mostly limited to the first pandemic wave in Germany, with only a few publications that study later phases of the pandemic or longer time horizons. While the insights gained from reviewing articles on the first pandemic wave are valuable, an inference of long-term trends is not advisable. Germany underwent several phases of the COVID-19 pandemic with diverse kinds of containment measures implemented at different points in time and with regional variations within Germany. Especially the first wave of the pandemic with the initial lockdown period may have acted as an initial shock, changing the behavior both in terms of lifestyle factors and medical help seeking behavior. Behavioral responses to the pandemic could change over time, e.g., due to less novelty value of the pandemic situation, or due to permanently adapting to a different lifestyle. Some studies hinted in their analysis, that some trends seemed to mitigate as time went on. Therefore, to draw conclusions on long-lasting trends or to observe differences between later periods throughout the pandemic, additional research would be needed. As the pandemic is still ongoing, new data emerges frequently and the current state of evidence improves constantly.

We also excluded empirical studies that reported a sample size of less than one hundred cases due to limited statistical power of results. However, this study selection might have introduced a bias to our results, especially for study designs where case numbers are generally small (e.g., single center studies).

Relating to the characteristics of the reviewed articles, we recognize that the comparability of study outcomes is limited between data on different CVDs, e.g., heart failure vs. stroke. Diagnoses discussed in the different studies ranged from CVD as a disease area to specific diagnoses such as TIA or ICH. We reported the direction of an effect or the general trend (increase, decrease), because effect sizes may in fact not be comparable between the different diagnoses. Patient characteristics such as age, gender, and comorbidities might also be drivers of results, which were not always reported in the reviewed articles. Not all authors reported statistical significance or confidence intervals for their report, limiting our ability to judge the quality of the data. More so, different authors used different control periods, from same year control to previous year control, to a previous 3-year control period. The selection of time horizons might also be an important driver of found effects, making the comparability of studies less clear.

While we evaluated the generalizability of the evidence presented in an article, several studies focused on specific geographic locations (single-center studies) or specific patient populations and due to their limited generalizability have not been cited extensively in the results. However, insight might still be valuable to the specific regional context or patient group.

Several articles on patient behavior and the treatment situation were based upon evidence drawn from hospital networks. Confounders related to the hospital network were not controlled for in these articles, such as hospital locations, hospital size, COVID-19 incidence at location or specialization of hospitals - which in turn makes the generalizability of the results and the assessment of driving factors behind the results more difficult. Furthermore, when only emergency hospital patients are included in analyses, the painted picture of treatment effects might not reflect the situation of elective non-urgent procedures. A similar limitation regarding generalizability relates to several of the included survey studies if they were based on a so-called convenience sample instead of applying a randomized

sampling method. As a result, specific groups may have been under- or over-represented in these studies, e.g., if older people were surveyed less frequently, and well-educated people were surveyed more frequently.

Finally, there are many possible confounders of the pandemic situation that were not controlled for. To give an example, door-to-balloon time could have decreased during the COVID-19 pandemic because people were advised to stay at home and hence there was less traffic on the roads.

4 Conclusion

The first objective of this study was to provide reliable and up-to-date figures on the health and socioeconomic burden of ASCVDs in Germany to create awareness for the importance of effective prevention. The second objective was to explore the possible impacts of the COVID-19 pandemic on CVDs in Germany, because early evidence suggested an association with an increase in CVD risk factors.

We considered disease events attributable to ten diagnoses separately for the 16 German federal states and accounted for losses in paid and unpaid work activities. Because ASCVD-related events disproportionally affect older age groups, focusing only on paid work would have ignored an important aspect of the socioeconomic burden.

ACSVD, such as myocardial infarction or ischemic stroke, is considered the primary preventable form of CVD. Therefore, the substantial number of inpatient stays and premature deaths associated with ASCVD diagnoses and the estimates on the socioeconomic burden shown in our analysis highlight the economic and societal benefits that effective prevention strategies could have in reducing this burden.

While the reviewed literature does not allow for inference of long-term trends, it indicates short-term impacts of the COVID-19 pandemic on behavioral CVD risk factors as well as on healthcare for CVDs. More information is necessary to better understand different mechanisms and the persistence of effects to deduct clear recommendations for action. For example, it would be important to understand what caused the shortened length of hospital stays and the decrease in hospital admission rates, i.e., did patients avoid healthcare facilities or did the pandemic circumstances decrease the risk to suffer from a CV event.

While unambiguous and generalizable evidence on COVID-19 is not yet available, the health and socioeconomic burden already point out a clear need to reduce CVD risk. Even if the pandemic does not have a homogeneous impact on individual risk factors, this cannot capture the risk that comes to play when multiple risk factors combine. Given the ongoing pandemic, relatively small impacts in different areas of life could cumulatively result in an increase (or decrease) of CVD risk. Therefore, future research should aim to investigate the interplay of different risk factors associated with the pandemic.

Bibliography

Al-Aly, Z., Xie, Y., & Bowe, B. (2021). High-dimensional characterization of post-acute sequelae of COVID-19. *Nature*, *594*(7862), 259–264. https://doi.org/10.1038/s41586-021-03553-9

Beckmann, A., Meyer, R., Lewandowski, J., Markewitz, A., & Gummert, J. (2021). German Heart Surgery Report 2020: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery. *The Thoracic and Cardiovascular Surgeon*, *69*(04), 294–307. https://doi.org/10.1055/s-0041-1730374

Behrendt, C.-A., Seiffert, M., Gerloff, C., L'Hoest, H., Acar, L., & Thomalla, G. (2021). How Does SARS-CoV-2 Infection Affect Survival of Emergency Cardiovascular Patients? A Cohort Study From a German Insurance Claims Database. *European Journal of Vascular and Endovascular Surgery*, *62*(1), 119–125. https://doi.org/10.1016/j.ejvs.2021.03.006

Böhm, M., Frey, N., Giannitsis, E., Sliwa, K., & Zeiher, A. M. (2020). Coronavirus Disease 2019 (COVID-19) and its implications for cardiovascular care: Expert document from the German Cardiac Society and the World Heart Federation. *Clinical Research in Cardiology*, *109*(12), 1446–1459. https://doi.org/10.1007/s00392-020-01656-3

Bollmann, A., Hohenstein, S., König, S., Meier-Hellmann, A., Kuhlen, R., & Hindricks, G. (2020). In-hospital mortality in heart failure in Germany during the Covid-19 pandemic. *ESC Heart Failure*, *7*(6), 4416–4419. https://doi.org/10.1002/ehf2.13011

Bollmann, A., Hohenstein, S., Pellissier, V., Stengler, K., Reichardt, P., Ritz, J.-P., Thiele, H., Borger, M. A., Hindricks, G., Meier-Hellmann, A., & Kuhlen, R. (2021). Utilization of in- and outpatient hospital care in Germany during the Covid-19 pandemic insights from the German-wide Helios hospital network. *PLOS ONE*, *16*(3), e0249251. https://doi.org/10.1371/journal.pone.0249251

Bollmann, A., Pellissier, V., Hohenstein, S., König, S., Ueberham, L., Meier-Hellmann, A., Kuhlen, R., Thiele, H., Hindricks, G., & Helios hospitals, Germany. (2021). Cumulative hospitalization deficit for cardiovascular disorders in Germany during the COVID-19 pandemic: Insights from the German-wide Helios hospital network. *European Heart Journal - Quality of Care and Clinical Outcomes*, *7*(4), e5–e6. https://doi.org/10.1093/ehjqcco/qcaa071

Bundesagentur für Arbeit (BA). (2020). *Blickpunkt Arbeitsmarkt—Fachkräfteengpassanalyse 2019* (Statistik/Arbeitsmarktberichterstattung). Bundesagentur für Arbeit.

Busse, H., Buck, C., Stock, C., Zeeb, H., Pischke, C. R., Fialho, P. M. M., Wendt, C., & Helmer, S. M. (2021). Engagement in Health Risk Behaviours before and during the COVID-19 Pandemic in German University Students: Results of a Cross-Sectional Study. *International Journal of Environmental Research and Public Health*, *18*(4), 1410. https://doi.org/10.3390/ijerph18041410

Damerow, S., Rommel, A., Prütz, F., Beyer, A.-K., Hapke, U., Schienkiewitz, A., Starker, A., Richter, A., Baumert, J., Fuchs, J., Gaertner, B., Müters, S., Lemcke, J., & Allen, J. (2020). Die gesundheitliche Lage der Bevölkerung zu Beginn der COVID-19-Pandemie. Zeitliche Entwicklung ausgewählter Indikatoren der Studie GEDA-EHIS 2019. *Journal of Health Monitoring*, *5*(4), 1–34. https://doi.org/10.25646/7171

Dornquast, C., Kroll, L. E., Neuhauser, H. K., Willich, S. N., Reinhold, T., & Busch, M. A. (2016). Regional Differences in the Prevalence of Cardiovascular Disease. *Deutsches Arzteblatt International*, *113*(42), 704–711. https://doi.org/10.3238/arztebl.2016.0704

Engels, E. S., Mutz, M., Demetriou, Y., & Reimers, A. K. (2021). Levels of physical activity in four domains and affective wellbeing before and during the Covid-19 pandemic. *Archives of Public Health*, *79*(1), 122. https://doi.org/10.1186/s13690-021-00651-y

Erdur, H., Siegerink, B., Leithner, C., Franke, C., Lorenz-Meyer, I., Theen, S., Angermaier, A., Kinze, S., Weber, J. E., Rohmann, J. L., Scheitz, J. F., Nolte, C. H., Endres, M., & Audebert, H. J. (2021). Stroke Admissions, Stroke Severity, and Treatment Rates in Urban and Rural Areas During the COVID-19 Pandemic. *Frontiers in Neurology*, *11*, 607193. https://doi.org/10.3389/fneur.2020.607193

EUnetHTA. (2015). *Methods for health economic evaluations—A guideline based on current practices in Europe*. European Network for Health Technology Assessment (EUnetHTA). https://eunethta.eu/wp-content/uploads/2018/01/Methods-for-health-economic-evaluations-A-guideline-based-on-current-practices-in-Europe_Guideline_Final-May-2015.pdf

European Union. (2013). *Revision of the European Standard Population—Report of Eurostat's task force*. doi:10.2785/11470

Eurostat. (2021). *European Union labour force survey (EU-LFS) 2019. Annual population by sex, degree of urbanization and labour status (1000) [lfsa_pgauws].* https://ec.europa.eu/eurostat/de/web/products-datasets/product?code=lfsa_pgauws

Georgiadou, E., Hillemacher, T., Müller, A., Koopmann, A., Lemenager, T., & Kiefer, F. (2020). Alkohol und Rauchen: Die COVID-19-Pandemie als idealer Nährboden für Süchte. *Deutsches Ärzteblatt*. https://www.aerzteblatt.de/archiv/214451/Alkohol-und-Rauchen-Die-COVID-19-Pandemie-als-idealer-Naehrboden-fuer-Suechte

Gesundheitsberichterstattung des Bundes. (2021). *Standardbevölkerungen*. https://www.gbe-bund.de/gbe/abrechnung.prc_abr_test_logon?p_uid=gast&p_aid=0&p_knoten=FID&p_sprache=D&p_suchstring=10216

Grzegorowska, O., & Lorkowski, J. (2020). Possible Correlations between Atherosclerosis, Acute Coronary Syndromes and COVID-19. *Journal of Clinical Medicine*, *9*(11), 3746. https://doi.org/10.3390/jcm9113746

Günster, C., Drogan, D., Hentschker, C., Klauber, J., Malzahn, J., Schillinger, G., & Mostert, C. (2020). WIdO-Report: Entwicklung der Krankenhausfallzahlen während des Coronavirus-Lockdowns. *Wissenschaftliches Institut Der AOK*.

Hofmann, S. (2015). *Einfluss nicht-marktlicher Tätigkeiten auf den materiellen Wohlstand und die Einkommensverteilung in Deutschland*. Frankfurt am Main [u.a.] : PL Acad. Research.

Institut für Arbeitsmarkt- und Berufsforschung (IAB). (2021). *Sonderauswertung der IAB Arbeitszeitrechnung für WifOR. Arbeitszeit und Arbeitsvolumen nach Geschlecht und Altersgruppen (Inland, abgestimmt auf VGR-Eckwerte)*.

Jaehn, P., Holmberg, C., Uhlenbrock, G., Pohl, A., Finkenzeller, T., Pawlik, M. T., Quack, I., Ernstberger, A., Rockmann, F., & Schreyer, A. G. (2021). Differential trends of admissions in accident and emergency departments during the COVID-19 pandemic in Germany. *BMC Emergency Medicine*, *21*(1), 42. https://doi.org/10.1186/s12873-021-00436-0

Jakstaite, A. M., Papathanasiou, M., & Lüdike, P. (2021). Myokarditis und COVID-19: Wo stehen wir? *Aktuelle Kardiologie*, *10*(01), 27–31. https://doi.org/10.1055/a-1314-9200

Kapsner, L. A., Kampf, M. O., Seuchter, S. A., Gruendner, J., Gulden, C., Mate, S., Mang, J. M., Schüttler, C., Deppenwiese, N., Krause, L., Zöller, D., Balig, J., Fuchs, T., Fischer, P., Haverkamp, C., Holderried, M., Mayer, G., Stenzhorn, H., Stolnicu, A., … Prokosch, H.-U. (2021). Reduced Rate of Inpatient Hospital Admissions in 18 German University Hospitals During the COVID-19 Lockdown. *Frontiers in Public Health*, *8*, 594117. https://doi.org/10.3389/fpubh.2020.594117

Kilian, C., Rehm, J., Allebeck, P., Braddick, F., Gual, A., Barták, M., Bloomfield, K., Gil, A., Neufeld, M., O'Donnell, A., Petruželka, B., Rogalewicz, V., Schulte, B., Manthey, J., & the European Study Group on Alcohol Use and COVID-19. (2021). Alcohol consumption during the COVID-19 pandemic in Europe: A large-scale cross-sectional study in 21 countries. *Addiction*, *116*(12), 3369–3380. https://doi.org/10.1111/add.15530

König, S., Hohenstein, S., Meier-Hellmann, A., Kuhlen, R., Hindricks, G., & Bollmann, A. (2020). In-hospital care in acute heart failure during the COVID-19 pandemic: Insights from the German-wide Helios hospital network. *European Journal of Heart Failure*, *22*(12), 2190–2201. https://doi.org/10.1002/ejhf.2044

König, S., Ueberham, L., Pellissier, V., Hohenstein, S., Meier-Hellmann, A., Thiele, H., Ahmadli, V., Borger, M. A., Kuhlen, R., Hindricks, G., Bollmann, A., & Helios hospitals, Germany. (2021). Hospitalization deficit of in- and outpatient cases with cardiovascular diseases and utilization of cardiological interventions during the COVID -19 pandemic: Insights from the German-wide helios hospital network. *Clinical Cardiology*, *44*(3), 392–400. https://doi.org/10.1002/clc.23549

Koopmann, A., Georgiadou, E., Reinhard, I., Müller, A., Lemenager, T., Kiefer, F., & Hillemacher, T. (2021). The Effects of the Lockdown during the COVID-19 Pandemic on Alcohol and Tobacco Consumption Behavior in Germany. *European Addiction Research*, *27*(4), 242–256. https://doi.org/10.1159/000515438

Koopmann, A., Müller, A., Lemenager, T., Hillemacher, T., Kiefer, F., & Georgiadou, E. (2021). Auswirkungen des Lockdowns im Frühjahr 2020 während der COVID-19-Pandemie auf das Ess- und Sportverhalten – Ergebnisse einer Onlinebefragung. *Diabetologie und Stoffwechsel*, *EFirst*.

Krol, M., Papenburg, J., Tan, S. S., Brouwer, W., & Hakkaart, L. (2016). A noticeable difference? Productivity costs related to paid and unpaid work in economic evaluations on expensive drugs. *The European Journal of Health Economics*, *17*(4), 391–402. https://doi.org/10.1007/s10198-015-0685-x

Kuhlmann, I., Chin, D., & Rimbach, G. (2015). *Prävention kardiovaskulärer Erkrankungen und Atherosklerose*. Springer Fachmedien Wiesbaden.

Mach, F., Baigent, C., Catapano, A. L., Koskinas, K. C., Casula, M., Badimon, L., Chapman, M. J., De Backer, G. G., Delgado, V., Ference, B. A., Graham, I. M., Halliday, A., Landmesser, U., Mihaylova, B., Pedersen, T. R., Riccardi, G., Richter, D. J., Sabatine, M. S., Taskinen, M.-R., … ESC Scientific Document Group. (2020).

2019 ESC/EAS Guidelines for the management of dyslipidaemias: Lipid modification to reduce cardiovascular risk. *European Heart Journal*, *41*(1), 111–188. https://doi.org/10.1093/eurheartj/ehz455

Maertl, T., De Bock, F., Huebl, L., Oberhauser, C., Coenen, M., Jung-Sievers, C., & on behalf of the COSMO Study Team. (2021). Physical Activity during COVID-19 in German Adults: Analyses in the COVID-19 Snapshot Monitoring Study (COSMO). *International Journal of Environmental Research and Public Health*, *18*(2), 507. https://doi.org/10.3390/ijerph18020507

Manthey, J., Kilian, C., Schomerus, G., Kraus, L., Rehm, J., & Schulte, B. (2020). Alkoholkonsum in Deutschland und Europa während der SARS-CoV-2 Pandemie. *SUCHT*, *66*(5), 247–258. https://doi.org/10.1024/0939-5911/a000686

Mata, J., Wenz, A., Rettig, T., Reifenscheid, M., Möhring, K., Krieger, U., Friedel, S., Fikel, M., Cornesse, C., Blom, A. G., & Naumann, E. (2021). Health behaviors and mental health during the COVID-19 pandemic: A longitudinal population-based survey in Germany. *Social Science & Medicine*, *287*, 114333. https://doi.org/10.1016/j.socscimed.2021.114333

Mattioli, A. V., Ballerini Puviani, M., Nasi, M., & Farinetti, A. (2020). COVID-19 pandemic: The effects of quarantine on cardiovascular risk. *European Journal of Clinical Nutrition*, *74*(6), 852–855. https://doi.org/10.1038/s41430-020-0646-z

Michalowsky, B., Hoffmann, W., Bohlken, J., & Kostev, K. (2021). Effect of the COVID-19 lockdown on disease recognition and utilisation of healthcare services in the older population in Germany: A cross-sectional study. *Age and Ageing*, *50*(2), 317–325. https://doi.org/10.1093/ageing/afaa260

Millán, M., Nagel, S., Gumbinger, C., Busetto, L., Purrucker, J. C., Hametner, C., Ringleb, P. A., & Mundiyanapurath, S. (2021). Differential effects of the SARS-CoV-2 pandemic on patients presenting to a neurological emergency room depending on their triage score in an area with low COVID-19 incidence. *European Journal of Neurology*, *28*(10), 3332–3338. https://doi.org/10.1111/ene.14709

Miranda, V. (2011). *Cooking, Caring and Volunteering: Unpaid Work Around the World* (OECD Social, Employment and Migration Working Papers No. 116; OECD Social, Employment and Migration Working Papers). https://doi.org/10.1787/5kghrjm8s142-en

Mostert, C., Hentschker, C., Scheller-Kreinsen, D., Günster, C., Malzahn, J., & Klauber, J. (2021). Auswirkungen der Covid-19-Pandemie auf die Krankenhausleistungen im Jahr 2020. In J. Klauber, J. Wasem, A. Beivers, & C. Mostert (Eds.), *Krankenhaus-Report 2021* (pp. 277–306). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-62708-2_16

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x

Mutz, M., & Gerke, M. (2021). Sport and exercise in times of self-quarantine: How Germans changed their behaviour at the beginning of the Covid-19 pandemic. *International Review for the Sociology of Sport*, *56*(3), 305–316. https://doi.org/10.1177/1012690220934335

Naujoks, F., Schweigkofler, U., Lenz, W., Blau, J., Brune, I., Lischke, V., Adler, H., Schindelin, I., Rouchi, H., Chobotsky, H., & Gottschalk, R. (2021). Veränderungen der rettungsdienstlichen Einsatzzahlen in einer Metropolregion während der ersten COVID-19-Pandemie-bedingten Kontaktbeschränkungsphase. *Notfall + Rettungsmedizin*. https://doi.org/10.1007/s10049-021-00875-z

Nef, H. M., Elsässer, A., Möllmann, H., Abdel-Hadi, M., Bauer, T., Brück, M., Eggebrecht, H., Ehrlich, J. R., Ferrari, M. W., Fichtlscherer, S., Hink, U., Hölschermann, H., Kacapor, R., Koeth, O., Korboukov, S., Lamparter, S., Laspoulas, A. J., Lehmann, R., Liebetrau, C., … CoVCAD –Study Group. (2021). Impact of the COVID-19 pandemic on cardiovascular mortality and catherization activity during the lockdown in central Germany: An observational study. *Clinical Research in Cardiology: Official Journal of the German Cardiac Society*, *110*(2), 292–301. https://doi.org/10.1007/s00392-020-01780-0

Palmer, K., Bschaden, A., & Stroebele-Benschop, N. (2021). Changes in lifestyle, diet, and body weight during the first COVID 19 'lockdown' in a student sample. *Appetite*, *167*, 105638. https://doi.org/10.1016/j.appet.2021.105638

Puntmann, V. O., Carerj, M. L., Wieters, I., Fahim, M., Arendt, C., Hoffmann, J., Shchendrygina, A., Escher, F., Vasa-Nicotera, M., Zeiher, A. M., Vehreschild, M., & Nagel, E. (2020). Outcomes of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From Coronavirus Disease 2019 (COVID-19). *JAMA Cardiology*, *5*(11), 1265. https://doi.org/10.1001/jamacardio.2020.3557

R Core Team. (2020). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org

Rattka, M., Dreyhaupt, J., Winsauer, C., Stuhler, L., Baumhardt, M., Rottbauer, W., & Imhof, A. (2021). Effekt der COVID-19-Pandemie und des Lockdowns auf die Inzidenz von Herzinfarktpatienten in Deutschland –

Ergebnisse einer Metaanalyse. *Der Kardiologe*, *15*(4), 407–411. https://doi.org/10.1007/s12181-021-00479-4

Reid, M. G. (1934). *Economics of household production*. New York: J. Wiley & Sons.

Richter, D., Eyding, J., Weber, R., Bartig, D., Grau, A., Hacke, W., & Krogias, C. (2021a). Analysis of Nationwide Stroke Patient Care in Times of COVID-19 Pandemic in Germany. *Stroke*, *52*(2), 716–721. https://doi.org/10.1161/STROKEAHA.120.033160

Richter, D., Eyding, J., Weber, R., Bartig, D., Grau, A., Hacke, W., & Krogias, C. (2021b). A full year of the COVID-19 pandemic with two infection waves and its impact on ischemic stroke patient care in Germany. *European Journal of Neurology*, ene.15057. https://doi.org/10.1111/ene.15057

Robert Koch-Institut. (2017). *12-Monats-Prävalenz von Schlaganfall oder chronischen Beschwerden infolge eines Schlaganfalls in Deutschland*. https://doi.org/10.17886/RKI-GBE-2017-010

Robert Koch-Institut, & Statistisches Bundesamt (Destatis). (2006). *Gesundheit in Deutschland 2006* (Gesundheitsberichterstattung Des Bundes). Robert Koch-Institut. https://www.rki.de/DE/Content/Gesundheitsmonitoring/Gesundheitsberichterstattung/GesInDtld/GiD_2006/gesundheitsbericht.html;jsessionid=E7B6CFE36081741A6676723245777F40.internet081?nn=7054960

RStudio Team. (2021). *RStudio: Integrated Development Environment for R*. RStudio, PBC. http://www.rstudio.com/

Saleh, A., Matsumori, A., Abdelrazek, S., Eltaweel, S., Salous, A., Neumann, F.-J., & Antz, M. (2020). Myocardial involvement in coronavirus disease 19. *Herz*, *45*(8), 719–725. https://doi.org/10.1007/s00059-020-05001-2

Schilling, J., Buda, S., Fischer, M., Goerlitz, L., Grote, U., Haas, W., Hamouda, O., Prahm, K., & Tolksdorf, K. (2021). *Retrospektive Phaseneinteilung der COVID-19-Pandemie in Deutschland bis Februar 2021*. https://doi.org/10.25646/8149

Scholz, K. H., Lengenfelder, B., Thilo, C., Jeron, A., Stefanow, S., Janssens, U., Bauersachs, J., Schulze, P. C., Winter, K. D., Schröder, J., vom Dahl, J., von Beckerath, N., Seidl, K., Friede, T., & Meyer, T. (2020). Impact of COVID-19 outbreak on regional STEMI care in Germany. *Clinical Research in Cardiology*, *109*(12), 1511–1521. https://doi.org/10.1007/s00392-020-01703-z

Seiffert, M., Brunner, F. J., Remmel, M., Thomalla, G., Marschall, U., L'Hoest, H., Acar, L., Debus, E. S., Blankenberg, S., Gerloff, C., & Behrendt, C.-A. (2020). Temporal trends in the presentation of cardiovascular and cerebrovascular emergencies during the COVID-19 pandemic in Germany: An analysis of health insurance claims. *Clinical Research in Cardiology*, *109*(12), 1540–1548. https://doi.org/10.1007/s00392-020-01723-9

Simon, O. J., Menzler, K., & Timmermann, L. (2021). Update 2021: COVID-19 aus Sicht der Neurologie. *DMW - Deutsche Medizinische Wochenschrift*, *146*(13/14), 918–923. https://doi.org/10.1055/a-1449-5098

Statistisches Bundesamt (Destatis). (2017a). *Herz-Kreislauf-Erkrankungen verursachen die höchsten Kosten*. Statistisches Bundesamt (Destatis). https://www.destatis.de/DE/Presse/Pressemitteilungen/2017/09/PD17_347_236pdf.html

Statistisches Bundesamt (Destatis). (2017b). *Sonderauswertung auf Basis von Daten der Zeitverwendungserhebung 2012/13. Durchschnittliche Zeitverwendung von Personen je Tag nach ausgewählten Aktivitäten, Personenmerkmalen und Altersgruppen*.

Statistisches Bundesamt (Destatis). (2020a). *Verdienststrukturerhebung 2018, Fachserie 16 Heft 1*.

Statistisches Bundesamt (Destatis). (2020b). *Volkswirtschaftliche Gesamtrechnungen, Inlandsproduktberechnung, detaillierte Jahresergebnisse 2019, Fachserie 18 Reihe 1.4*.

Statistisches Bundesamt (Destatis). (2021a). *Bevölkerung: Bundesländer, Stichtag, Geschlecht, Altersjahre (Stichtage 31.12.2018, 31.12.2019)*. Statistisches Bundesamt (Destatis), Genesis-Online, Datenlizenz by-2-0.

Statistisches Bundesamt (Destatis). (2021b). *Krankenhauspatienten: Bundesländer, Jahre, Geschlecht, Altersgruppen, Hauptdiagnose ICD-10 (1-3-Steller Hierarchie)—2019*. Statistisches Bundesamt (Destatis), Genesis-Online, Datenlizenz by-2-0.

Statistisches Bundesamt (Destatis). (2021c). *Patienten in Vorsorge- oder Rehabilitationseinrichtungen: Deutschland, Jahre, Geschlecht, Altersgruppen, Wohnort des Patienten, Hauptdiagnose ICD-10 (1-3-Steller Hierarchie)—2019*. Statistisches Bundesamt (Destatis), Genesis-Online, Datenlizenz by-2-0.

Statistisches Bundesamt (Destatis). (2021d). *Sonderauswertung der Todesursachenstatistik für Deutschland—3-stellige ICD-Klassifikation nach Bundesländern, Altersgruppen und Geschlecht—2019*. Statistisches Bundesamt (Destatis).

Statistisches Bundesamt (Destatis). (2021e). *Sterbetafeln: Ergebnisse aus der laufenden Berechnung von Periodensterbetafeln für Deutschland und die Bundesländer—2018/2020*. Statistisches Bundesamt (Destatis).

Statistisches Bundesamt (Destatis). (2021f). *VGR des Bundes—Bruttolöhne und -gehälter: Deutschland, Jahre, Wirtschaftsbereiche—2019*. Statistisches Bundesamt (Destatis), Genesis-Online, Datenlizenz by-2-0.

Statistisches Bundesamt (Destatis). (2021g). *Tiefgegliederte Diagnosedaten der Krankenhauspatientinnen und -patienten—2019*. Statistisches Bundesamt (Destatis).

Statistisches Bundesamt (Destatis). (2021h, November 4). *Anzahl der Gestorbenen nach Kapiteln der und nach Geschlecht für 2020*. Statistisches Bundesamt. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Gesundheit/Todesursachen/Tabellen/gestorbene_anzahl.html

Stöhr, E., Aksoy, A., Campbell, M., Al Zaidi, M., Öztürk, C., Vorloeper, J., Lange, J., Sugiura, A., Wilde, N., Becher, M. U., Diepenseifen, C., Heister, U., Nickenig, G., Zimmer, S., & Tiyerili, V. (2020). Hospital admissions during Covid-19 lock-down in Germany: Differences in discretionary and unavoidable cardiovascular events. *PLOS ONE*, *15*(11), e0242653. https://doi.org/10.1371/journal.pone.0242653

Tanislav, C., Jacob, L., & Kostev, K. (2021). Consultations Decline for Stroke, Transient Ischemic Attack, and Myocardial Infarction during the COVID-19 Pandemic in Germany. *Neuroepidemiology*, 1–8. https://doi.org/10.1159/000513812

Tiedt, S., for the GSR-ET investigators, Bode, F. J., Uphaus, T., Alegiani, A., Gröschel, K., & Petzold, G. C. (2020). Impact of the COVID-19-pandemic on thrombectomy services in Germany. *Neurological Research and Practice*, *2*(1), 44. https://doi.org/10.1186/s42466-020-00090-0

Tolksdorf, K., Buda, S., & Schilling, J. (2021). *Aktualisierung zur "Retrospektiven Phaseneinteilung der COVID-19-Pandemie in Deutschland."* https://doi.org/10.25646/8961

Ueberham, L., König, S., Pellissier, V., Hohenstein, S., Meier-Hellmann, A., Kuhlen, R., Hindricks, G., & Bollmann, A. (2021). Admission rates and care pathways in patients with atrial fibrillation during the COVID-19 pandemic—Insights from the German-wide Helios hospital network. *European Heart Journal - Quality of Care and Clinical Outcomes*, *7*(3), 257–264. https://doi.org/10.1093/ehjqcco/qcab011

Uphaus, T., Gröschel, S., Hayani, E., Hahn, M., Steffen, F., & Gröschel, K. (2020). Stroke Care Within the COVID-19 Pandemic—Increasing Awareness of Transient and Mild Stroke Symptoms Needed. *Frontiers in Neurology*, *11*, 581394. https://doi.org/10.3389/fneur.2020.581394

Vacanti, G., Bramlage, P., Schymik, G., Schmitt, C., Luik, A., Swojanowsky, P., & Tzamalis, P. (2020). Reduced rate of admissions for acute coronary syndromes during the COVID-19 pandemic: An observational analysis from a tertiary hospital in Germany. *Herz*, *45*(7), 663–667. https://doi.org/10.1007/s00059-020-04991-3

Vollmuth, C., Miljukov, O., Abu-Mugheisib, M., Angermaier, A., Barlinn, J., Busetto, L., Grau, A. J., Guenther, A., Gumbinger, C., Hubert, N., Hüttemann, K., Klingner, C., Naumann, M., Palm, F., Remi, J., Rücker, V., Schessl, J., Schlachetzki, F., Schuppner, R., … Hubert, G. J. (2021). Impact of the coronavirus disease 2019 pandemic on stroke teleconsultations in Germany in the first half of 2020. *European Journal of Neurology*, *28*(10), 3267–3278. https://doi.org/10.1111/ene.14787

von der Schulenburg, J.-M. G., Greiner, W., Jost, F., Klusen, N., Kubin, M., Leidl, R., Mittendorf, T., Rebscher, H., Schoeffski, O., Vauth, C., Volmer, T., Wahler, S., Wasem, J., & Weber, C. (2008). German Recommendations on Health Economic Evaluation: Third and Updated Version of the Hanover Consensus. *Value in Health*, *11*(4), 539–544. https://doi.org/10.1111/j.1524-4733.2007.00301.x

Waterall, J. (2019, February 14). *Health Matters: Preventing cardiovascular disease* [Blog]. Public Health Matters. https://publichealthmatters.blog.gov.uk/2019/02/14/health-matters-preventing-cardiovascular-disease/

Wienbergen, H., Retzlaff, T., Schmucker, J., Marin, L. A. M., Rühle, S., Garstka, D., Osteresch, R., Fach, A., & Hambrecht, R. (2021). Impact of COVID-19 Pandemic on Presentation and Outcome of Consecutive Patients Admitted to Hospital Due to ST-Elevation Myocardial Infarction. *The American Journal of Cardiology*, *151*, 10–14. https://doi.org/10.1016/j.amjcard.2021.04.011

Woods, J. A., Hutchinson, N. T., Powers, S. K., Roberts, W. O., Gomez-Cabrera, M. C., Radak, Z., Berkes, I., Boros, A., Boldogh, I., Leeuwenburgh, Christiaan, Coelho-Júnior Hélio José, Marzetti, E., Cheng, Y., Liu, J., Durstine, L. J., Sun, J., & Ji, L. L. (2020). The COVID-19 pandemic and physical activity. *Sports Medicine and Health Science*, *2*(2), 55–64. https://doi.org/10.1016/j.smhs.2020.05.006

World Health Organization. (2021, June 11). *Cardiovascular diseases (CVDs) Fact Sheet*. World Health Organization. https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Zeymer, U., Gitt, A., & Thiele, H. (2021). COVID-19-Pandemie: Effekte auf die klinische Versorgung von Herz-Kreislauf-Patienten im Frühling 2020. *Herz*, *46*(2), 115–119. https://doi.org/10.1007/s00059-020-05015-w

Appendix

Appendix A: Additional information on estimation of health and socioeconomic burden

Annex 1: Data sources and socioeconomic input parameters in the base case scenario

Data /Parameter		Source
Health		
Inpatient hospitalizations		(Statistisches Bundesamt (Destatis), 2021b, 2021g)
Duration of hospital stay (in days)	stratified by - main diagnosis (three-digit ICD-10-GM code) - age groups - gender - German federal states	(Statistisches Bundesamt (Destatis), 2021b, 2021g)
Inpatient rehabilitations		(Statistisches Bundesamt (Destatis), 2021c)
Duration of rehab stay (in days)		(Statistisches Bundesamt (Destatis), 2021c)
Death cases		(Statistisches Bundesamt (Destatis), 2021d)
Life expectancy (in years)	stratified by - age groups - gender	(Statistisches Bundesamt (Destatis), 2021e)
Employment characteristics		

Employment rate

Age group	Men	Women	
20-24	69.0%	65.4%	(Eurostat, 2021)
25-29	84.0%	77.1%	
30-34	89.7%	77.4%	
35-39	91.0%	80.0%	
40-44	91.3%	83.1%	
45-49	91.2%	84.8%	
50-54	90.1%	83.3%	
55-59	85.6%	77.9%	
60-64	66.6%	57.1%	
65-69	22.1%	14.0%	
70-74	11.1%	5.6%	
75+	3.2%	1.2%	

Average actual working hours (paid work) per day

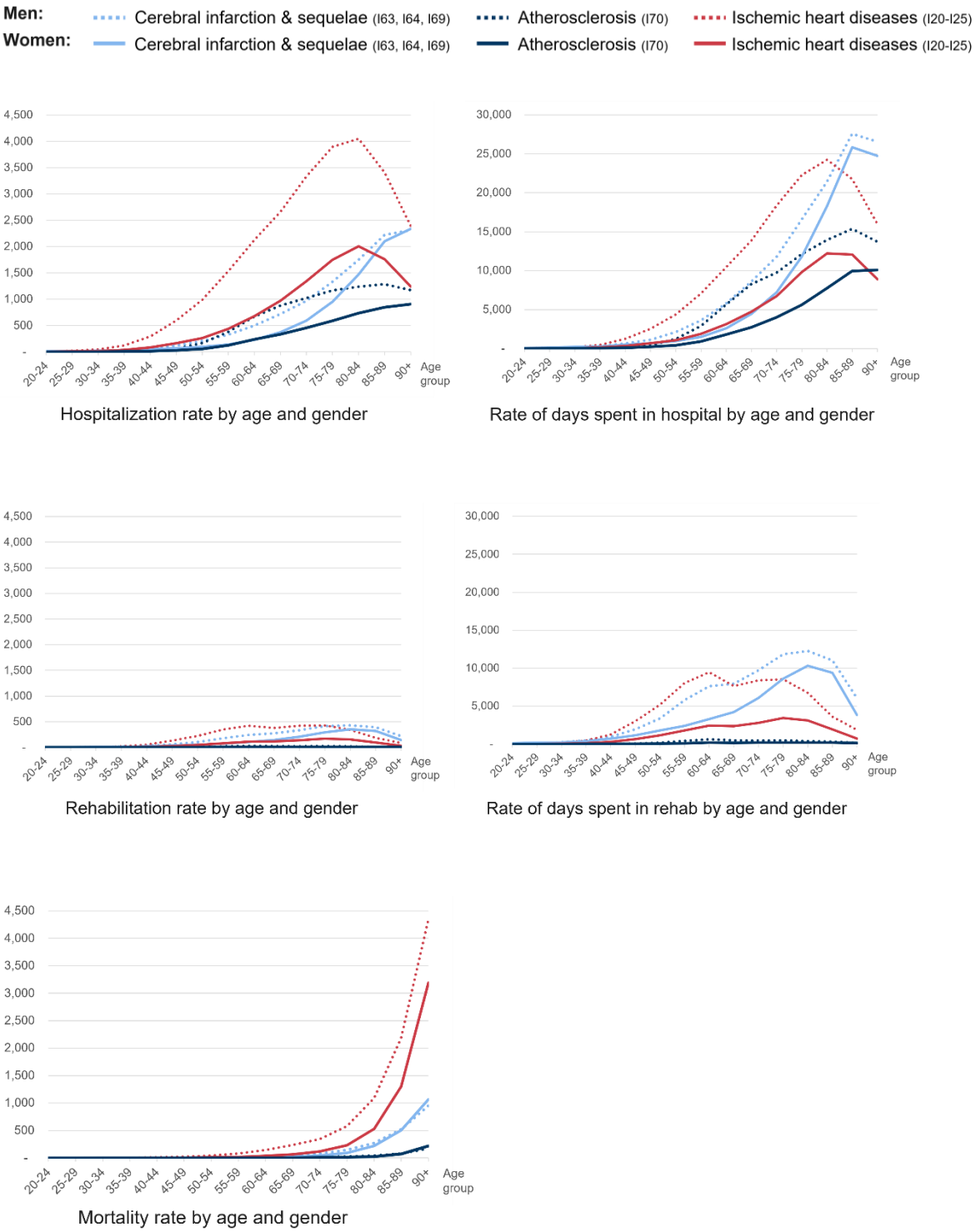
Age group	Men	Women	
20-24	3.90	3.35	(Institut für Arbeitsmarkt- und Berufsforschung (IAB), 2021)
25-29	4.25	3.48	
30-34	4.49	3.22	
35-39	4.58	3.16	
40-44	4.67	3.31	
45-49	4.68	3.38	
50-54	4.69	3.39	
55-59	4.52	3.29	
60-64	3.99	2.94	
65+	2.35	1.61	

Average gross hourly wage	€ 27.75	(Statistisches Bundesamt (Destatis), 2020b)

Unpaid work characteristics			
Unpaid work activities, average hours per day*			
Age group	Men	Women	
20-29	1.32	2.27	(Statistisches Bundesamt (Destatis), 2017b)
30-39	2.37	4.55	
40-49	2.38	3.95	
50-59	2.37	3.77	
60-64	2.90	4.03	
65-69	3.25	4.15	
70-74	3.30	4.40	
75-79	3.00	4.00	
80+	2.53	3.47	
Average specialist gross hourly wage**			
Age group	Men	Women	
20-29	€ 20.18	€ 20.07	(Statistisches Bundesamt (Destatis), 2021f)
30-39	€ 21.49	€ 21.75	
40-49	€ 20.35	€ 19.75	
50-59	€ 19.11	€ 18.53	
60-64	€ 18.89	€ 18.21	
65-69	€ 19.00	€ 17.79	
70-74	€ 18.75	€ 18.30	
75-79	€ 18.03	€ 17.69	
80+	€ 17.42	€ 17.62	
Other model parameters			
Discount rate for future productivity losses	3.0%		(EUnetHTA, 2015)

Notes: *Including the following unpaid work activities: Gardening and animal care, preparation of meals, improvements and home repair, maintenance of dwelling, care of textile fabrics, purchases and procurement, day-to-day organization, informal care, childcare, voluntary work. **Average values were calculated according to the age and gender specific composition of unpaid work activities that were assigned to different industry sectors as their closest market substitute.

Annex 2: Relative health burden associated with selected ASCVD diagnoses in 2019 (crude rate per 100,000)



Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis) (see section 2.1). Rounded numbers.

Annex 3: Hospitalizations, rehabilitations, and death cases due to ASCVD diagnoses in 2019 by federal state

Federal state	Inpatient hospitalizations			Rehabilitation cases			Death cases		
	Absolute number	Crude rate per 100,000	Standardized rate	Absolute number	Crude rate per 100,000	Standardized rate	Absolute number	Crude rate per 100,000	Standardized rate
Schleswig-Holstein	36,851	1,557	1,090	5,294	224	162	5,928	250	178
Hanseatic City of Hamburg	25,591	1,705	1,469	1,963	131	113	2,564	171	145
Lower Saxony	96,165	1,483	1,069	18,369	283	205	17,245	266	193
Bremen	12,179	2,186	1,686	1,114	200	158	1,315	236	178
North Rhine-Westphalia	253,662	1,742	1,305	33,393	229	171	29,933	206	153
Hesse	74,834	1,468	1,115	12,006	236	179	11,574	227	174
Rhineland-Palatinate	52,431	1,569	1,141	8,463	253	184	8,319	249	181
Baden-Württemberg	124,857	1,392	1,069	25,249	281	216	18,108	202	156
Bavaria	159,554	1,494	1,150	26,111	244	186	22,254	208	163
Saarland	17,584	2,134	1,472	3,088	375	261	2,373	288	195
Berlin	55,289	1,847	1,550	5,051	169	141	5,750	192	166
Brandenburg	36,469	1,753	1,151	6,530	314	208	6,059	291	197
Mecklenburg-Western Pomerania	25,703	1,922	1,280	4,487	336	226	4,326	324	218
Saxony	51,234	1,522	995	9,196	273	184	11,153	331	205
Saxony-Anhalt	37,678	2,044	1,321	7,060	383	253	6,329	343	222
Thuringia	32,881	1,849	1,201	6,631	373	247	5,129	288	190
Total	***1,092,963***	***-***	***-***	***174,005***	***-***	***-***	***158,359***	***-***	***-***
Average value	***-***	***1,729***	***1,254***	***-***	***269***	***193***	***-***	***255***	***182***

Source: Own calculations based on data provided by Statistisches Bundesamt (Destatis) (see section 2.1). Rounded numbers.
Results were adjusted for age distribution and gender ratio according to the European Standard Population (European Union, 2013) to present the standardized rate per 100,000 inhabitants.

Appendix B: Additional information on literature search

Annex 4: Keywords used in PubMed search

Main keyword category	(1) COVID-19	(2) Cardiovascular disease	(3) Treatment decisions	(4) Lifestyle adjustments	(5) Geographic location
Keywords within main category	COVID 19 COVID-19 Virus Disease(s) COVID 19 Virus Disease Disease, COVID-19 Virus Virus Disease, COVID-19 COVID-19 Virus Infection(s) COVID 19 Virus Infection Infection, COVID-19 Virus Virus Infection, COVID-19 2019-nCoV Infection(s) 2019 nCoV Infection Infection, 2019-nCoV Coronavirus Disease-19 Coronavirus Disease 19 2019 Novel Coronavirus Disease 2019 Novel Coronavirus Infection 2019-nCoV Disease(s) 2019 nCoV Disease Disease, 2019-nCoV COVID19 Coronavirus Disease 2019 Disease 2019, Coronavirus SARS Coronavirus 2 Infection SARS-CoV-2 Infection(s) Infection, SARS-CoV-2 SARS CoV 2 Infection COVID-19 Pandemic(s) COVID 19 Pandemic Pandemic, COVID-19 SARS-CoV-2 SARS virus COVID-19 Coronavirus Coronavirus disease 2019 Severe acute respiratory syndrome coronavirus 2 Severe acute respiratory syndrome COVID-19 pandemic 2019 novel coronavirus 2019-nCoV Human coronavirus 2019 HCoV-19 hCoV-19 "COVID-19"[Mesh]	Acute coronary syndrome CVD Atherosclerosis Cardiovascular Cardiovascular disease Cardiovascular risk Cardiovascular system Cardiovascular event Acute heart failure Stroke Myocardial infarction Myocardial injury Myocarditis Heart failure Cerebrovascular Cerebrovascular disease Cerebrovascular risk Cerebrovascular event Cerebrovascular system Ischemic stroke Endothelial dysfunction Ischaemic Stroke Acute Ischemic Stroke Ischemic Stroke, Acute Stroke, Acute Ischemic Primary percutaneous coronary intervention "Ischemic Stroke"[Mesh] "Arteriosclerosis"[Mesh] "Cardiovascular Diseases"[Mesh]	Delivery of Healthcare Healthcare Deliveries Healthcare Delivery Health Care Delivery Health Care Healthcare Health Care System(s) Healthcare System(s) Patient Acceptance of Healthcare Healthcare Patient Acceptance(s) Health Care Seeking Behavior Health Care Utilization Healthcare Utilization Length of stay Hospitalization Hospital visit Patient visit Rebound Delay Delay of treatment Admission rate Postponement Postpone "Health Behavior"[Mesh] "Hospitalization"[Mesh] "Delivery of Health Care"[Mesh] "Patient Acceptance of Health Care"[Mesh]	Nutrition Physical activity Lifestyle adjustment Exercise Diet Cooking Weight Obesity Health behavior(s) Health behaviour(s) Coping strategy Coping strategies Vigorous activity Moderate activity Walking Calorie intake Dietary intake Nutritional intake Step counts Overweight Tobacco Alcohol "Exercise"[Mesh] "Overweight"[Mesh] "Tobacco Use"[Mesh] "Alcohol Drinking"[Mesh] "Eating"[Mesh]	Germany German Germany[Mesh]

Note: We accounted for different spellings and selected plural forms by adding an “s” at the word ending (indicated by parenthesis).

Annex 5: Query translation for main keyword categories in PubMed

Main keyword category	**Query translation** (31 August, 2021)
(1) COVID-19	("covid 19"[Title/Abstract] OR "covid 19 virus disease"[Title/Abstract] OR "covid 19 virus disease"[Title/Abstract] OR "disease covid 19 virus"[Title/Abstract] OR "virus disease covid 19"[Title/Abstract] OR "covid 19 virus infection"[Title/Abstract] OR "covid 19 virus infection"[Title/Abstract] OR "COVID-19 Virus Infections"[Title/Abstract] OR "virus infection covid 19"[Title/Abstract] OR "2019 ncov infection"[Title/Abstract] OR "2019 ncov infection"[Title/Abstract] OR "2019-nCoV Infections"[Title/Abstract] OR "infection 2019 ncov"[Title/Abstract] OR "coronavirus disease 19"[Title/Abstract] OR "coronavirus disease 19"[Title/Abstract] OR "2019 Novel Coronavirus Disease"[Title/Abstract] OR "2019 Novel Coronavirus Infection"[Title/Abstract] OR "2019 ncov disease"[Title/Abstract] OR "2019 ncov disease"[Title/Abstract] OR "2019-nCoV Diseases"[Title/Abstract] OR "disease 2019 ncov"[Title/Abstract] OR "COVID19"[Title/Abstract] OR "coronavirus disease 2019"[Title/Abstract] OR "disease 2019 coronavirus"[Title/Abstract] OR "SARS Coronavirus 2 Infection"[Title/Abstract] OR "sars cov 2 infection"[Title/Abstract] OR "infection sars cov 2"[Title/Abstract] OR "sars cov 2 infection"[Title/Abstract] OR "SARS-CoV-2 Infections"[Title/Abstract] OR "covid 19 pandemic"[Title/Abstract] OR "covid 19 pandemic"[Title/Abstract] OR "COVID-19 Pandemics"[Title/Abstract] OR "pandemic covid 19"[Title/Abstract] OR "SARS-CoV-2"[Title/Abstract] OR "SARS virus"[Title/Abstract] OR "covid 19"[Title/Abstract] OR "Coronavirus"[Title/Abstract] OR "coronavirus disease 2019"[Title/Abstract] OR "severe acute respiratory syndrome"[Title/Abstract] OR "Severe acute respiratory syndrome coronavirus 2"[Title/Abstract] OR "covid 19 pandemic"[Title/Abstract] OR "2019 novel coronavirus"[Title/Abstract] OR "2019-nCoV"[Title/Abstract] OR "Human coronavirus 2019"[Title/Abstract] OR "hcov 19"[Title/Abstract] OR "hcov 19"[Title/Abstract] OR "covid 19"[MeSH Terms]) AND (english[Filter] OR german[Filter])
(2) Cardiovascular disease	("Acute coronary syndrome"[Title/Abstract] OR "CVD"[Title/Abstract] OR "Atherosclerosis"[Title/Abstract] OR "Cardiovascular"[Title/Abstract] OR "Cardiovascular disease"[Title/Abstract] OR "Cardiovascular risk"[Title/Abstract] OR "Cardiovascular system"[Title/Abstract] OR "Cardiovascular event"[Title/Abstract] OR "Acute heart failure"[Title/Abstract] OR "Stroke"[Title/Abstract] OR "Myocardial infarction"[Title/Abstract] OR "Myocardial injury"[Title/Abstract] OR "Myocarditis"[Title/Abstract] OR "Heart failure"[Title/Abstract] OR "Cerebrovascular"[Title/Abstract] OR "Cerebrovascular disease"[Title/Abstract] OR "Cerebrovascular risk"[Title/Abstract] OR "Cerebrovascular event"[Title/Abstract] OR "Cerebrovascular system"[Title/Abstract] OR "ischemic stroke"[Title/Abstract] OR "Endothelial dysfunction"[Title/Abstract] OR "Ischaemic Stroke"[Title/Abstract] OR "Acute Ischemic Stroke"[Title/Abstract] OR "ischemic stroke acute"[Title/Abstract] OR "stroke acute ischemic"[Title/Abstract] OR "primary percutaneous coronary intervention"[Title/Abstract] OR "ischemic stroke"[MeSH Terms] OR "Arteriosclerosis"[MeSH Terms] OR "Cardiovascular Diseases"[MeSH Terms]) AND (english[Filter] OR german[Filter])
(3) Treatment decisions	("Delivery of Healthcare"[Title/Abstract] OR "Healthcare Deliveries"[Title/Abstract] OR "Healthcare Delivery"[Title/Abstract] OR "Health Care Delivery"[Title/Abstract] OR "Health Care"[Title/Abstract] OR "Healthcare"[Title/Abstract] OR "Health Care Systems"[Title/Abstract] OR "Health Care System"[Title/Abstract] OR "Healthcare Systems"[Title/Abstract] OR "Healthcare System"[Title/Abstract] OR "Patient Acceptance of Healthcare"[Title/Abstract] OR "Health Care Seeking Behavior"[Title/Abstract] OR "Health Care Utilization"[Title/Abstract] OR "Healthcare Utilization"[Title/Abstract] OR "length of stay"[Title/Abstract] OR "Hospitalization"[Title/Abstract] OR "hospital visit"[Title/Abstract] OR "patient visit"[Title/Abstract] OR "Rebound"[Title/Abstract] OR "Delay"[Title/Abstract] OR "Delay of treatment"[Title/Abstract] OR "admission rate"[Title/Abstract] OR "postponement"[Title/Abstract] OR "Postpone"[Title/Abstract] OR "Health Behavior"[MeSH Terms] OR "Hospitalization"[MeSH Terms] OR "Delivery of Health Care"[MeSH Terms] OR "Patient Acceptance of Health Care"[MeSH Terms]) AND (english[Filter] OR german[Filter])

Main keyword category	**Query translation** (31 August, 2021)
(4) Lifestyle adjustments	("Nutrition"[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "Lifestyle adjustment"[Title/Abstract] OR "Exercise"[Title/Abstract] OR "Diet"[Title/Abstract] OR "Cooking"[Title/Abstract] OR "Weight"[Title/Abstract] OR "Obesity"[Title/Abstract] OR "Health behaviours"[Title/Abstract] OR "Health behaviors"[Title/Abstract] OR "Health behaviour"[Title/Abstract] OR "Health behavior"[Title/Abstract] OR "Coping strategy"[Title/Abstract] OR "Coping strategies"[Title/Abstract] OR "Vigorous activity"[Title/Abstract] OR "Moderate activity"[Title/Abstract] OR "Walking"[Title/Abstract] OR "Step counts"[Title/Abstract] OR "Overweight"[Title/Abstract] OR "Tobacco"[Title/Abstract] OR "Alcohol"[Title/Abstract] OR "Calorie Intake"[Title/Abstract] OR "Dietary Intake"[Title/Abstract] OR "Nutritional Intake"[Title/Abstract] OR "Exercise"[MeSH Terms] OR "Overweight"[MeSH Terms] OR "Tobacco Use"[MeSH Terms] OR "Alcohol Drinking"[MeSH Terms] OR "Eating"[MeSH Terms]) AND (english[Filter] OR german[Filter])
(5) Geographic location	("Germany"[Title/Abstract] OR "German"[Title/Abstract] OR "Germany"[MeSH Terms]) AND (english[Filter] OR german[Filter])

Annex 6: Combination of keyword categories and search history in PubMed

Research question to answer	Search date	Combination of keyword categories	Hits	Comment
a)	August 31, 2021	1 & 2 & 3	3,258	
a)	August 31, 2021	1 & 2 & 3 & 5	71	These Germany-specific records were included in title /abstract screening
b)	August 31, 2021	1 & 4	9,706	
b)	August 31, 2021	1 & 4 & 5	140	These Germany-specific records were included in title /abstract screening
c), d)	August 31, 2021	1 & 2	12,171	
c), d)	August 31, 2021	1 & 2 & 5	153	These Germany-specific records were included in title /abstract screening
O**verlap between searches**	August 31, 2021	(1 & 2 & 5) not (1 & 2 & 3 & 5)	82	Hits from search on c), d) minus overlap with search on question a)
	August 31, 2021	(1 & 2 & 3 & 5) not (1 & 2 & 5)	0	All hits from search on question a) included in hits from search on c), d)

Annex 7: Information collected during title and abstract screening

Category	Explanation
Reviewer ID	Initials of reviewers
Decision on relevance: yes /no	Does the article provide information to answer one of our research questions?
Answer to which sub-question?	a, b, c, d
Exclusion criterion	If article is excluded, which is the main reason /criterion
Article type	e.g., literature review, meta-analysis, overview, opinion, editorial, original research article, (…)
Independent or explanatory variable?	COVID-19 infection or pandemic situation
Dependent variable of interest	e.g., CVD outcomes, risk for CVD, delay of treatment, eating behavior, alcohol consumption, (…)
Specific population	Does the article focus on a specific sub-population, e.g., nurses or nursing home residents?
Adult study population	Does the article focus on adults, children, or both?

Annex 8: German keywords used in Google Scholar search

Main keyword category	(1) COVID-19	(2) Cardiovascular disease	(3) Treatment decisions	(4) Lifestyle adjustments	(5) Geographic location
Keywords within main category	COVID-19 2019-nCoV SARS-CoV-2	Koronarsyndrom CVD Atherosklerose Herzinsuffizienz Herzinfarkt ischämischer Schlaganfall Herz-Kreislauf-System kardiovaskulär Schlaganfall Myokardinfarkt	Gesundheits-versorgung Erstkontakt	Ernährung körperliche Bewegung Sport Tabak Alkohol Übergewicht psychische Gesundheit Gesundheits-verhalten	Deutschland

Annex 9: Query translation and search history in Google Scholar

Research question to answer	Search date	Combination of keyword categories	Query translation	Hits	Comment
a)	September 14, 2021	1 & 2 & 3	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Koronarsyndrom“ OR „CVD“ OR „Atherosklerose“ OR „Herzinsuffizienz“ OR „Herzinfarkt“ OR „ischämischer Schlaganfall“) AND („Gesundheitsversorgung“ OR „Erstkontakt")	Title /abstract pre-screening results in 26 hits	
a)	October 01, 2021	1 & 2 & 3	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Koronarsyndrom“ OR „Herz-Kreislauf-System” OR „Atherosklerose“ OR „kardiovaskulär “ OR „ischämischer Schlaganfall“) AND („Gesundheitsversorgung“ OR „Erstkontakt")	No additional results in second title /abstract pre-screening to search on 14-Sep 2021	Change in search terms: Instead of “CVD“ we used “Herz-Kreislauf-System” (because of English acronym); instead of “Herzinfarkt” and “Herzinsuffizienz” we used “kardiovaskulär”.
b)	September 14, 2021	1 & 4 & 5	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Ernährung“ OR „körperliche Bewegung“ OR „Sport“ OR „Tabak“ OR „Alkohol“ OR „Übergewicht“ OR „psychische Gesundheit“) AND („Deutschland“)	Title /abstract pre-screening results in 20 hits	Query b_i
b)	October 01, 2021	1 & 4 & 5	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Ernährung“ OR „körperliche Bewegung“ OR „Sport“ OR „Tabak“ OR „Alkohol“ OR „Übergewicht“ OR „Gesundheitsverhalten“) AND („Deutschland“)	Eleven additional results in second title /abstract pre-screening to search on 14-Sep 2021	Query b_i Following our decision to exclude articles with mental health focus, “psychische Gesundheit” was replaced by „Gesundheitsverhalten“.
b)	September 14, 2021	1 & 2 & 4	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („CVD“ OR „Herzinfarkt“ OR „Schlaganfall“) AND („Ernährung“ OR „körperliche Bewegung“ OR „Tabak“ OR „Alkohol“ OR „Übergewicht“ OR „psychische Gesundheit“)	Title /abstract pre-screening results in 31 hits	b_{ii}

b)	October 01, 2021	1 & 2 & 4	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Herz-Kreislauf-System“ OR „Schlaganfall“) AND („Ernährung“ OR „körperliche Bewegung“ OR „Tabak“ OR „Alkohol“ OR „Übergewicht“ OR „Gesundheitsverhalten“)	Three additional results in second title /abstract pre-screening to search on 14-Sep 2021	b_{ii} Following our decision to exclude articles with mental health focus, “psychische Gesundheit” was replaced by „Gesundheitsverhalten“. “CVD” and „Herzinfarkt” were changed to “Herz-Kreislauf-System”.
c), d)	September 14, 2021	1 & 2 & 5	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Koronarsyndrom“ OR „CVD“ OR „Atherosklerose“ OR „Herzinsuffizienz“ OR „Herzinfarkt“ OR „Myokardinfarkt“ OR „ischämischer Schlaganfall“) AND („Deutschland“)	Title /abstract pre-screening results in 25 hits	
c), d)	October 01, 2021	1 & 2 & 5	(„COVID-19“ OR „2019-nCoV“ OR „SARS-CoV-2“) AND („Koronarsyndrom“ OR „ Herz-Kreislauf-System“ OR „Atherosklerose“ OR „kardiovaskulär“ OR „Myokardinfarkt“ OR „ischämischer Schlaganfall“) AND („Deutschland“)	Fourteen additional results in second title /abstract pre-screening to search on 14-Sep 2021	Change in search terms: Instead of “CVD“ we used “Herz-Kreislauf-System” (because of English acronym); instead of “Herzinfarkt” and “Herzinsuffizienz” we used “kardiovaskulär”.

Annex 10: List of articles covering aspects of healthcare provision or utilization during the COVID-19 pandemic

Outcome	Number of articles	Authors
Patient characteristics	1	(Vollmuth et al., 2021)
Comorbidities	1	(König et al., 2020)
CVD mortality in general	1	(Nef et al., 2021)
30-day rate of readmissions	1	(König et al., 2020)
Functional outcome at discharge	1	(Tiedt et al., 2020)
Changes in severity of events /severity of disease	5	i) (Erdur et al., 2021) ii) (König et al., 2020) iii) (Millán et al., 2021) iv) (Mostert et al., 2021) v) (Wienbergen et al., 2021)
Hospital workflow and delay of treatment	5	i) (Millán et al., 2021) ii) (Richter et al., 2021a) iii) (Scholz et al., 2020) iv) (Tiedt et al., 2020) v) (Wienbergen et al., 2021)
Other healthcare utilization, ambulatory care	5	i) (Damerow et al., 2020) ii) (Michalowsky et al., 2021) iii) (Naujoks et al., 2021) iv) (Tanislav et al., 2021) v) (Vollmuth et al., 2021)
Operations /procedures	6	i) (Beckmann et al., 2021) ii) (König et al., 2021) iii) (Richter et al., 2021a) iv) (Richter et al., 2021b) v) (Uphaus et al., 2020) vi) (Vollmuth et al., 2021)
Length of hospital stay	7	i) (Bollmann et al., 2020) ii) (Bollmann, Hohenstein, et al., 2021)) iii) (König et al., 2020) iv) (Mostert et al., 2021) v) (Nef et al., 2021) vi) (Ueberham et al., 2021) vii) (Uphaus et al., 2020)
Survival rates /in-hospital mortality	10	i) (Behrendt et al., 2021) ii) (Bollmann et al., 2020) iii) (Bollmann, Hohenstein, et al., 2021) iv) (König et al., 2020) v) (Nef et al., 2021) vi) (Richter et al., 2021a) vii) (Richter et al., 2021b) viii) (Scholz et al., 2020) ix) (Seiffert et al., 2020) x) (Wienbergen et al., 2021)

Outcome	Number of articles	Authors
Hospital admission rates	22	i) (Bollmann et al., 2020) ii) (Bollmann, Hohenstein, et al., 2021) iii) (Bollmann, Pellissier, et al., 2021) iv) (Erdur et al., 2021) v) (Günster et al., 2020) vi) (Jaehn et al., 2021) vii) (Kapsner et al., 2021) viii) (König et al., 2020) ix) (König et al., 2021) x) (Millán et al., 2021) xi) (Mostert et al., 2021) xii) (Nef et al., 2021) xiii) (Rattka et al., 2021) xiv) (Richter et al., 2021a) xv) (Scholz et al., 2020) xvi) (Seiffert et al., 2020) xvii) (Stöhr et al., 2020) xviii) (Tiedt et al., 2020) xix) (Ueberham et al., 2021) xx) (Uphaus et al., 2020) xxi) (Vacanti et al., 2020) xxii) (Wienbergen et al., 2021)

Source: Results from own literature review.

Annex 11: List of articles covering behavioral CVD risk factors during the COVID-19 pandemic

Outcome	Number of articles	Authors
Bodyweight	2	i) (Damerow et al., 2020) ii) (Palmer et al., 2021)
Eating behavior	3	i) (Koopmann, Müller, et al., 2021) ii) (Mata et al., 2021) iii) (Palmer et al., 2021)
Tobacco consumption	4	i) (Busse et al., 2021) ii) (Damerow et al., 2020) iii) (Georgiadou et al., 2020) iv) (Koopmann, Georgiadou, et al., 2021)
Alcohol consumption	5	i) (Busse et al., 2021) ii) (Georgiadou et al., 2020) iii) (Kilian et al., 2021) iv) (Koopmann, Georgiadou, et al., 2021) v) (Manthey et al., 2020)
Physical activity	7	i) (Busse et al., 2021) ii) (Engels et al., 2021) iii) (Koopmann, Müller, et al., 2021) iv) (Maertl et al., 2021) v) (Mata et al., 2021) vi) (Mutz & Gerke, 2021) vii) (Palmer et al., 2021)

Source: Results from own literature review.

WifOR is an independent economic research institute that originated from a spin-out of the Department of Public Economics and Economic Policy at the Technical University of Darmstadt, Germany. We see ourselves as an academic partner and think tank on a global scale. WifOR's fields of research include Economic, Environmental and Social Impact Analyses as well as Labour Market and Health Economy research.

CONTACT

WifOR Institute
Rheinstraße 22
D-64283 Darmstadt
Germany | Greece | Ireland | Latin America | USA

www.wifor.com