COVID-19 related decline in cancer screenings most pronounced for elderly patients and women in Germany: a claims data analysis

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Abstract
Purpose This study aimed to analyze the utilization of cancer screenings in Germany before and during the COVID-19 pandemic in 2020. The objective of the analysis was to identify the population at particular risk and to derive recommendations for the future use of resources to prevent long-term deteriorations in health outcomes.

Methods The analysis was conducted based on claims data of all preventive health services for 15,833,662 patients from the largest statutory health insurance fund in Germany. Utilization of general female cancer screening, general male cancer screening, general health checkup, colorectal cancer screening stool test, colorectal cancer screening consultation, colonoscopy, skin cancer screening, and mammography screening was compared before (2017–2019) and during (2020) the pandemic.

Results Data of a total of 42,046,078 observed screenings showed that the utilization of the individual screenings developed differently, but that the overall utilization decreased significantly by 21.46% during the COVID-19 pandemic (p < 0.001). At the same time, no catch-up effects were detected for total screenings throughout the entire year 2020. The highest decline in screenings was found for the elderly (p < 0.001) and women (p < 0.001).

Conclusion Because the elderly are at higher risk for cancer, the omission of early detection might lead to higher treatment costs, reduced quality of life, and higher mortality. In addition, women's medical care in particular has been negatively affected, for example, by the interruption of mammography screenings and the lack of catch-up effects. Therefore, resources must be targeted to reduce burdens on health outcomes and public health in the long term.

Keywords Claims data analysis · COVID-19 · Cancer screening · Gender inequalities · Age inequalities · Public health

Background
Noncommunicable diseases such as cancer and cardiovascular diseases have a negative impact on public health by causing approximately 71% of deaths worldwide each year. Moreover, they are associated with reduced quality of life and lower life expectancy, as well as economic burdens in the form of rising treatment costs and declining productivity (Dzau et al. 2017; World Economic Forum 2017; World Health Organization 2021). Preventive health services are an important component of public health as early detection and treatment of noncommunicable diseases such as cancer and their precursors can reduce incidence, disease severity, and mortality (World Health Organization. Regional Office for Europe 2020). As a result, countries around the world, including Germany, offer screening programs that are legally regulated. For example, since 2008, a skin cancer screening program has been offered free of charge for patients with statutory health insurance (SHI) in Germany. The program’s effects were desirable from a public health perspective: since its introduction, an increased incidence of skin cancer has been observed, but the cases detected were mainly in earlier stages of the disease (Girbig et al. 2021). Especially in malignant melanoma, early diagnosis and treatment are crucial as it has a direct impact on the survival rates (Girbig et al. 2021; McBain et al. 2021). Early diagnosis also plays an important role in successful treatment for other types of cancer, underlining the relevance of preventive health
services for health-care systems (World Health Organization. Regional Office for Europe 2010).

The screening program in Germany comprises a total of ten different services and primarily focuses on the early detection of cancer. Only the screening for colorectal cancer, cervical cancer, and breast cancer is organized and eligible patients are invited based on a register, while other screenings can be utilized opportunistically. Screening utilization varies in Germany with respect to the individual examinations, sex, and age. For example, more than 50% of women younger than 70 years make use of female cancer screening every 3 years. Male cancer screening, on the other hand, is only used by up to 35% in at least 5 out of 10 years. In total, participation rates were relatively constant before the COVID-19 pandemic (Tillmanns et al. 2021).

With the spread of the COVID-19 pandemic since March 2020 (World Health Organization. Regional Office for Europe 2022), however, international health-care systems have been disrupted (World Health Organization 2020). In addition to the direct medical impact from infections and associated mortality, the pandemic has led to widespread limitations in medical services (Wang et al. 2020). For example, a change in the utilization of outpatient services such as for cancer screenings was observed internationally (Chen et al. 2021; Damerow et al. 2020; Doubova et al. 2021). The postponed or canceled screenings, however, could be linked to the risk of delayed diagnosis and, thus, more severe disease progressions and the duration of suspended screenings and potential catch-up effects will have a strong impact on long-term death rates (Alkatout et al. 2021; Blumen et al. 2016; Burger et al. 2021; Duffy et al. 2022; Kregting et al. 2021; Maringe et al. 2020; Yong et al. 2021).

Compared to international findings, scientific publications on the utilization of preventive health services during the pandemic based on German data are limited (Alkatout et al. 2021; Mayo et al. 2021). However, to contain the impact of postponed and canceled screenings in Germany and to best prevent poorer health outcomes, increased mortality and rising health-care expenditures, a targeted use of limited health-care resources is essential in the long term. Prioritization of particularly vulnerable patient groups is only possible if differences in utilization are known, which can only be derived from examining trends across all preventive health services offered in a country and goes beyond simply analyzing individual screenings.

This explorative study attempts to fill the existing research gap by analyzing the utilization of all preventive health services and cancer screenings legally regulated for German patients using claims data from 15,833,662 patients in the SHI before and during the COVID-19 pandemic to identify the population at particular risk and to derive recommendations for the best possible use of resources in future preventive health programs. In addition, the change in outpatient reimbursement of screenings before and during COVID-19 will be compared in the form of a health economic analysis as part of this study.

Methods

Study design and data source

The retrospective claims data analysis was based on national claims data from adult persons who were insured at the AOK between 2017 and 2020. AOK consists of 11 regional health-care funds and together they represent the largest SHI fund in Germany. With 27 million insured persons, around one-third of the entire German population is covered by AOK (AOK-Bundesverband 2022; Schulz et al. 2020).

The data analyzed in the study were provided by the AOK Research Institute (WIdO) and served the primary purpose of the reimbursement of services between providers and payers. WIdO processed the requested data on the basis of a predefined study protocol and made them available for the purpose of the study. The study protocol was prepared in accordance with the guideline for Good Practice of Secondary Data Analysis (GPS) (Swart et al. 2015). In addition, the Consensus German Reporting Standard for Secondary Data Analyses, Version 2 (STROSA 2) was used as a guidance for the reporting of the study, as it was developed especially for the particular requirements of German claims data analyses (Swart et al. 2016).

The anonymized data set contained the claims data of the fee schedule items (GOP) for all preventive health services legally regulated for adult persons with SHI coverage in Germany. These included GOP 01730, 01760, and 01761 for general female cancer screening, 01731 for general male cancer screening, 01732 for general health checkup, 01734 and 01738 for colorectal cancer screening stool test, 01740 for colorectal cancer screening consultation, 01741 for colonoscopy, 01745 and 01746 for skin cancer screenings, 01747 for breast cancer screening, 01749 for prostate cancer screening, and 01750 for mammography. Beyond these GOPs, the data set included claims data for regionally agreed services for the listed screenings. Only claims data for early detection of abdominal aortic aneurysms were omitted because a complete data set for this preventive health service was not available for the observation period of the study. The term “screening” will be used synonymously for all preventive health services considered in the study.

The data set comprised the aggregated number of claims data on a monthly basis from January 2017 to December 2020, specified by the age and sex of patients eligible for the respective examinations. Age categories were formed on the age calculated at the end of December 2020. Only the claims data of AOK were used, and no further data linkage
was performed. Table 1 provides an overview of the data obtained.

**Sample and population**

The study included all AOK insured persons who were 25 years and older, eligible for the individual screenings based on their age and sex, insured in all quarters from 2017 to 2020, and who did not die in the fourth quarter of 2020. Patients that were participating in a primary physician model were excluded from the data set for data protection reasons. An a priori sample size calculation was not performed due to the explorative study design.

**Legal basis and data protection**

Claims data are transferred to the AOK according to § 295 of the German Social Code, Book V. The transfer of social data such as claims data for the purpose of research is regulated in § 67b and § 75 of the Social Code, Book X. As the data holder, the WIdO has consented to the provision of the data for the exclusive purpose of this study, taking into account data protection measures. Because the data set submitted by the WIdO only contained the aggregated number of screenings, the anonymized data did not allow any conclusions about individual persons. For this reason, no informed consent was required from the individuals included in the data set. Furthermore, according to the GPS guideline, the consultation of an ethics committee is not required for analyses of claims data (Swart et al. 2015).

**Data processing, statistical analyses, and health economic analysis**

During data preparation, the age categories 25–39 years, 40–59 years, 60–79 years, and > 80 years from a study by Kremer and Thurner (2020) were used to further summarize the age of the patients (Kremer and Thurner 2020). In addition, to compare utilization of screenings before COVID-19 and during COVID-19, the number of claimed screenings in the years 2017, 2018, and 2019 were averaged. This approach was intended to compensate for potential bias in previous years and to provide an approximation of the actual effects of the pandemic. Thus, the average utilization values from 2017 to 2019 were set as the time before COVID-19. Although the COVID-19 pandemic was declared as such not before March 2020, the first cases were reported in January 2020, which is why the values from 2020 were declared as the time during COVID-19 in the context of this study for the simplicity of the calculation.

The arithmetic mean and standard deviation (SD) of the change in monthly screening utilization before and during the COVID-19 pandemic were calculated using the observations from each GOP differentiated by sex and age category. Due to the sex- and age-based eligibility of the screenings, the total number of data points for the calculation of the mean and SD of each screening was 37 per month. Concerning the evaluation of differences in the utilization of screenings between women and men, only screenings that were available to both sexes were considered, resulting in a calculation of the mean and SD from a total of 14 data points per month per sex. Statistical analysis included the conduction of the binominal test to examine whether utilization changed significantly during the COVID-19 pandemic compared with the time before COVID-19. For this purpose, the respective proportion of utilized screenings during COVID-19 was compared with the proportion of utilized screenings before COVID-19 based on the number of insured persons that did not change during the observation period. This analysis comprised the individual GOPs, sex, and age of the patients. In addition, the independence of screening utilization before and during COVID-19 over the time course was tested using Pearson’s Chi-square test. This analysis was furthermore extended by distinguishing between sex and age categories. Effect sizes were calculated using Cramer’s V. The p value was set a priori at 0.05 to test two-sided significance. The Bonferroni–Holm correction was applied due to the multiple testing. Because of the small p values, even after adjustment

| Table 1 Overview of the screenings and eligible patients considered

| GOP    | Type of examination                      | Sex          | Agea  |
|--------|----------------------------------------|--------------|-------|
| 01730, 01760, 01761 | General female cancer screening          | Female       | ≥ 25 years  |
| 01731  | General male cancer screening           | Male         | ≥ 50 years  |
| 01732  | General health checkup                  | Female and Male| ≥ 40 years  |
| 01734, 01738 | Colorectal cancer screening stool test | Female and Male| ≥ 55 years  |
| 01740  | Colorectal cancer screening consultation| Female and Male| ≥ 55 years  |
| 01741  | Colonoscopy                            | Female and Male| ≥ 60 years  |
| 01745, 01746 | Skin cancer screening                    | Female and Male| ≥ 40 years  |
| 01750  | Mammography screening                   | Female       | ≥ 55–69 years |

aThe age groups were raised by 5 years compared to the actual eligibility for the respective preventive health services, as the age of the patients was calculated at the end of 2020.
based on the number of tests performed in the respective tables, the original $p$ values did not change and thus the Bonferroni–Holm correction had no effect on the reported results.

To be able to depict the change in preventive health services financially, the study compared outpatient reimbursement before and during COVID-19. For this purpose, the German uniform value scale (EBM) for outpatient billing of services provided by the SHI was considered. The calculation of the compensation for the respective GOPs studied was based on the four quarters of the years 2017–2020. Changes in the reimbursement of GOPs within the quarters considered were taken into account. Time before COVID-19 represented the average costs of the years 2017, 2018, and 2019. The calculation included the multiplication of the reimbursement of the individual GOPs with the number of screenings performed, which were provided by the WIdO. If simultaneous billing of several GOPs was not possible, the mean value of the reimbursement was used for the calculation (this was the case for GOPs 01760 and 01761 as well as 01745 and 01746).

**Results**

**Total utilization**

In total, data from 15,833,662 AOK insured individuals in the following age categories were included: (1) 25–39 years: 1,908,846 (female), 2,013,686 (male); (2) 40–59 years: 2,731,103 (female), 2,832,784 (male); (3) 60–79 years: 2,371,561 (female), 2,113,089 (male); (4) ≥ 80 years: 1,229,909 (female), 632,684 (male).

These patients attended 11,225,261 screenings in 2017, 11,353,234 screenings in 2018, and 10,743,594 screenings in 2019. This resulted in an average of 11,107,363 screenings per year before COVID-19 (averages for the years 2017–2019). During COVID-19 (in the year 2020), the number of screenings decreased significantly by 21.46% to 8,723,989 ($p < 0.001$). With 5.99% less examinations, the smallest decrease was seen in general male cancer screening ($p = 0.124$ for the general health checkup). The largest drop was seen in April 2020 for mammography ($p = 0.091$). In addition to the analysis of the total screenings, claims data for individual GOPs were examined on a monthly basis. A significant association in the time course of utilization was also detected for each individual screening at the $p < 0.001$ significance level. The largest effect size was found to be $V = 0.221$ for mammography screening, followed by $V = 0.124$ for the general health checkup. Effect sizes of the other screenings were lower.

The monthly change in the individual GOPs revealed a decline in utilization in most cases when comparing the before COVID-19 and during COVID-19 time horizon. The largest drop was seen in April 2020 for mammography screenings with a 98.71% decrease compared to before COVID-19. The general health checkup, with an average of 70.03% fewer utilizations in April 2020, was also affected greatly compared to the previous years’ levels. The percentage change in utilization, however, differed between screenings. While some screenings were performed less frequently, other screenings were requested more frequently in the same month than before COVID-19. For example, more colorectal
cancer screening consultations were utilized each month starting in June than in the same period before COVID-19. Comparing all GOPs, demand for colorectal cancer screening consultations increased the most, whereas demand for general health checkups decreased the most.

**Differences in utilization with regard to sex and age**

Beyond the consideration of the general utilization of screenings, differences due to patients’ sex and age were analyzed in more detail. Over the course of COVID-19, utilization of total screenings available to women decreased significantly by 20.56% from 7,450,140 before COVID-19 to 5,918,073 ($p < 0.001$) and for men by 23.28% from 3,657,223 to 2,805,916 ($p < 0.001$). In the age group 25–39 years, the utilization of total screenings decreased by 4.56% ($p < 0.001$), in the age group 40–59 years by 18.65% ($p < 0.001$), in the age group 60–79 years by 23.75% ($p < 0.001$), and for patients aged 80 years or older by 37.02% ($p < 0.001$). These results can be found in Table 4.

The mean percentage change in the monthly utilization of screenings before and during COVID-19 was differentiated between women and men in Fig. 2. Only GOPs that could be claimed for both sexes were considered. The mean utilization of screenings has declined to a greater extent for females.

| GOP                                      | Utilization | $z$-value | $q$ | $p$   |
|------------------------------------------|-------------|-----------|-----|-------|
| Total screenings                         |             | -1313.88  | 0.298| $< 0.001$ |
| Before COVID-19                          | 11,107,363  |           |     |       |
| During COVID-19                          | 8,723,989   |           |     |       |
| Change (%)                               | -21.46%     |           |     |       |
| General female cancer screening          |             | -212.84   | 0.779| $< 0.001$ |
| Before COVID-19                          | 3,492,421   |           |     |       |
| During COVID-19                          | 3,147,838   |           |     |       |
| Change (%)                               | -9.87%      |           |     |       |
| General male cancer screening            |             | -64.56    | 0.935| $< 0.001$ |
| Before COVID-19                          | 1,027,356   |           |     |       |
| During COVID-19                          | 965,852     |           |     |       |
| Change (%)                               | -5.99%      |           |     |       |
| General health checkup                   |             | -842.22   | 0.822| $< 0.001$ |
| Before COVID-19                          | 2,811,569   |           |     |       |
| During COVID-19                          | 1,536,466   |           |     |       |
| Change (%)                               | -45.35%     |           |     |       |
| Colorectal cancer screening stool test   |             | -257.44   | 0.96 | $< 0.001$ |
| Before COVID-19                          | 583,324     |           |     |       |
| During COVID-19                          | 392,478     |           |     |       |
| Change (%)                               | -32.72%     |           |     |       |
| Colorectal cancer screening consultation |             | 80.12     | 0.96 | $< 0.001$ |
| Before COVID-19                          | 638,853     |           |     |       |
| During COVID-19                          | 695,823     |           |     |       |
| Change (%)                               | 8.92%       |           |     |       |
| Colonoscopy                              |             | -43.64    | 0.995| $< 0.001$ |
| Before COVID-19                          | 85,341      |           |     |       |
| During COVID-19                          | 66,919      |           |     |       |
| Change (%)                               | -21.59%     |           |     |       |
| Skin cancer screening                    |             | -375.68   | 0.878| $< 0.001$ |
| Before COVID-19                          | 1,931,488   |           |     |       |
| During COVID-19                          | 1,442,453   |           |     |       |
| Change (%)                               | -25.32%     |           |     |       |
| Mammography screening                    |             | -86.23    | 0.966| $< 0.001$ |
| Before COVID-19                          | 537,010     |           |     |       |
| During COVID-19                          | 476,160     |           |     |       |
| Change (%)                               | -11.33%     |           |     |       |
than for males in each month when compared to the average utilization before COVID-19. The strongest difference between the sexes was observed in April. While the mean decrease in utilization for males was 54.48% (SD = 24.34%), females utilized on average 60.92% fewer screenings (SD = 20.07%) in April compared with the previous years’ average. However, for the months July and October through December, the overlapping SD suggests that in relation to the time period before COVID-19, the difference in screening utilization between sexes became smaller. The smallest difference in the mean percentage change to the time period before COVID-19 was observed in October (female: mean = −13.37%, SD = 18.96%; male: mean = −12.63%, SD = 20.17%).

Furthermore, in Table 5 sex differences are examined in more detail for the entire year 2020 compared with the before COVID-19 period for screenings that were available to both women and men. The decrease in total utilization of screenings was significantly more pronounced for women than for men during COVID-19. The largest difference between sexes was found for colonoscopy with a drop of 23.32% for women and 19.64% for men (χ²(1) = 21, p < 0.001, V = 0.012). The largest decrease in examinations offered for both sexes was observed for the general health checkup with a decrease of 46.47% for women and 43.93% for men (χ²(1) = 531, p < 0.001, V = 0.011). Colorectal cancer screening consultation increased for women and men during COVID-19 compared to before COVID-19. While women used these examinations on average 7.51% more often, the demand increased by an average of 10.72% for men compared to previous years (χ²(1) = 71, p < 0.001, V = 0.007).

Detailed tables of monthly screening utilization by women and men before and during COVID-19 are provided in Appendix 2 and 3.

Differences in the change of utilization could also be observed with regard to the age of the patients, as presented in Table 6. The change in utilization of total screenings was significantly related to patient age (χ²(2) = 14,559, p < 0.001, V = 0.038). The higher the age of the patients, the lower was the utilization of total screenings. While there were 27.11% fewer screenings in total recorded in the 40–59 years age category, the decline was 31.84% in the 60–79 years age category, and reached a maximum of 42.49% fewer screenings in the > 80 years age category. In addition, a significant decrease in utilization with increasing age was observed for all examinations, for which both women and men were eligible. Only the colorectal cancer screening stool test had a greater decrease in utilization among those aged 55–59 years (−36.96%) than among those aged 60–79 years (−28.18%). Nevertheless, the greatest decline was again found among those > 80 years of age (−41.66%) (χ²(2) = 1558, p < 0.001, V = 0.040). For colorectal cancer screening consultations, an increase in utilization during COVID-19 of 36.73% was observed among patients in the age category 55–59 years compared with before COVID-19. For patients aged 60–79 years, utilization changed by −0.41% and patients > 80 years had a decrease in utilization of 9.02% (χ²(2) = 8354, p < 0.001, V = 0.079). Another greater difference was found for colonoscopy, which showed
Table 3 Time course and screening utilization before and during COVID-19

| GOP screenings                  | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total screenings |
|---------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------------|
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 1,215,844       |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 988,555         |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | -18.69%         |
| General female cancer screening |     |     |     |     |     |     |     |     |     |     |     |     | 368,213         |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 348,193         |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 280,048         |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | -23.54%         |
| General male cancer screening   |     |     |     |     |     |     |     |     |     |     |     |     | 115,109         |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 104,241         |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 92,413          |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | +9.82%          |
| General health checkup          |     |     |     |     |     |     |     |     |     |     |     |     | 343,938         |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 307,212         |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 249,182         |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | -21.66%         |
| Colorectal cancer screening     |     |     |     |     |     |     |     |     |     |     |     |     | 63,503          |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 47,195          |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 35,684          |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | -28.08%         |
| Colonoscopy                     |     |     |     |     |     |     |     |     |     |     |     |     | 80,575          |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 57,583          |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 42,283          |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | +30.33%         |
| Skin cancer screening           |     |     |     |     |     |     |     |     |     |     |     |     | 208,776         |
| **Before COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 186,521         |
| **During COVID-19**             |     |     |     |     |     |     |     |     |     |     |     |     | 174,472         |
| **Change (%)**                  |     |     |     |     |     |     |     |     |     |     |     |     | -6.57%          |

\[ \chi^2 = 164,057, \ df = 11, \ p < 0.001, \ V = 0.091 \]

\[ \chi^2 = 38,226, \ df = 11, \ p < 0.001, \ V = 0.076 \]

\[ \chi^2 = 10,208, \ df = 11, \ p < 0.001, \ V = 0.072 \]

\[ \chi^2 = 66,487, \ df = 11, \ p < 0.001, \ V = 0.124 \]

\[ \chi^2 = 7613, \ df = 11, \ p < 0.001, \ V = 0.088 \]

\[ \chi^2 = 6157, \ df = 11, \ p < 0.001, \ V = 0.068 \]

\[ \chi^2 = 731, \ df = 11, \ p < 0.001, \ V = 0.069 \]

\[ \chi^2 = 24,560, \ df = 11, \ p < 0.001, \ V = 0.085 \]
a 17.87% reduction in the number of cases in the 60–79 years age category and a 54.32% reduction in the > 80 years age category ($\chi^2(1) = 890, p < 0.001, V = 0.076$). The utilization by age groups can be found in Appendix 4 for women, and in Appendix 5 for men.

### Health economic analysis

The results of the health economic analysis revealed notable variations in the reimbursement of preventive health services for SHI patients before and during COVID-19. The calculation in Table 7 shows that before COVID-19 a yearly mean of €274,937,166 was reimbursed for screenings and checkups. During COVID-19, reimbursement decreased to €219,378,343, resulting in a reduction of €55,558,823. The smallest decrease was noted in general male cancer screenings at €432,939, whereas the largest decrease was present in the general health checkups at €36,973,751. The only screening that was billed more often during COVID-19 was the colorectal cancer screening consultation with a change of €1,570,553.
Fig. 2 Percentage change in monthly utilization of screenings before and during COVID-19 comparing women and men

Table 5 Comparison of utilization between sex before and during COVID-19 for screenings available to both women and men

| GOP                                      | Female | Male    | $\chi^2$ | df | $p$   | V   |
|------------------------------------------|--------|---------|----------|----|-------|-----|
| Total screenings                         |        |         |          |    |       |     |
| Before COVID-19                          | 3,420,708 | 2,629,867 |          |    | <0.001 | 0.010 |
| During COVID-19                          | 2,294,075 | 1,840,064 |          |    |       |     |
| Change (%)                               | –32.94% | –30.03% |          |    |       |     |
| General health checkup                   |        |         |          |    |       |     |
| Before COVID-19                          | 1,574,858 | 1,236,711 |          |    | <0.001 | 0.011 |
| During COVID-19                          | 842,988 | 693,478 |          |    |       |     |
| Change (%)                               | –46.47% | –43.93% |          |    |       |     |
| Colorectal cancer screening stool test   |        |         |          |    |       |     |
| Before COVID-19                          | 364,352 | 218,973 |          |    | <0.001 | 0.013 |
| During COVID-19                          | 240,043 | 152,435 |          |    |       |     |
| Change (%)                               | –34.12% | –30.39% |          |    |       |     |
| Colorectal cancer screening consultation |        |         |          |    |       |     |
| Before COVID-19                          | 358,816 | 280,037 |          |    | <0.001 | 0.007 |
| During COVID-19                          | 385,754 | 310,069 |          |    |       |     |
| Change (%)                               | +7.51%  | +10.72% |          |    |       |     |
| Colonoscopy                              |        |         |          |    |       |     |
| Before COVID-19                          | 45,048 | 40,293 |          |    | <0.001 | 0.012 |
| During COVID-19                          | 34,541 | 32,378 |          |    |       |     |
| Change (%)                               | –23.32% | –19.64% |          |    |       |     |
| Skin cancer screening                    |        |         |          |    |       |     |
| Before COVID-19                          | 1,077,634 | 853,853 |          |    | <0.001 | 0.010 |
| During COVID-19                          | 790,749 | 651,704 |          |    |       |     |
| Change (%)                               | –26.62% | –23.67% |          |    |       |     |
Discussion

Key findings

The aim of this claims data analysis was to investigate the utilization of all preventive health services and cancer screenings offered to SHI patients in Germany before and during the COVID-19 pandemic. The study revealed two major findings. First, the utilization of total screenings decreased during the COVID-19 pandemic, but trends in utilization varied with respect to individual screenings. Second, screening utilization has developed differently among patient groups.

Change in screening utilization

The analysis showed that the number of total screenings decreased significantly in Germany by around 21.46% in 2020 compared to before COVID-19 ($p < 0.001$). In addition, the 4-year observation period revealed a decrease

### Table 6 Comparison of utilization between age before and during COVID-19

| GOP | 40–59 years | 60–79 years | > 80 years | $\chi^2$ | df | p   | V   |
|-----|-------------|-------------|------------|---------|-----|-----|-----|
| Total screenings | 2,367,027 | 2,727,664 | 955,885 | 14,559 | 2   | <0.001 | 0.038 |
| Before COVID-19 | 1,725,231 | 1,859,157 | 549,751 |          |     |      |     |
| During COVID-19 | – 27.11% | – 31.84% | – 42.49% |          |     |      |     |
| General health checkup | 1,205,688 | 1,149,165 | 465,716 | 12,244 | 2   | <0.001 | 0.053 |
| Before COVID-19 | 735,828 | 596,004 | 204,634 |          |     |      |     |
| During COVID-19 | – 38.97% | – 48.14% | – 55.19% |          |     |      |     |
| Colorectal cancer screening stool test | 156,597 | 332,382 | 94,345 | 1558 | 2   | <0.001 | 0.040 |
| Before COVID-19 | 98,721 | 238,720 | 55,037 |          |     |      |     |
| During COVID-19 | – 36.96% | – 28.18% | – 41.66% |          |     |      |     |
| Colorectal cancer screening consultation | 181,986 | 363,951 | 92,916 | 8354 | 2   | <0.001 | 0.079 |
| Before COVID-19 | 248,832 | 362,455 | 84,536 |          |     |      |     |
| During COVID-19 | + 36.73% | – 0.41% | – 9.02% |          |     |      |     |
| Colonoscopy | 76,645 | 8696 | 92,916 | 890 | 1   | <0.001 | 0.076 |
| Before COVID-19 | 62,947 | 3972 | 39,946 |          |     |      |     |
| During COVID-19 | – 17.87% | – 54.32% | – 21.99% |          |     |      |     |
| Skin cancer screening | 822,756 | 805,520 | 303,212 | 2334 | 2   | <0.001 | 0.026 |
| Before COVID-19 | 641,850 | 599,031 | 201,572 |          |     |      |     |
| During COVID-19 | – 21.99% | – 25.63% | – 33.52% |          |     |      |     |

*Data from patients ≥ 55 years

### Table 7 Change in outpatient reimbursement for screenings before and during COVID-19

| GOP | Reimbursement before COVID-19 | Reimbursement during COVID-19 | Change |
|-----|-----------------------------|-----------------------------|--------|
| Total screenings | €274,937,166 | €219,378,343 | –55,558,823 |
| General female cancer screening | €67,057,068 | €59,944,056 | –7,113,012 |
| General male cancer screening | €15,680,030 | €15,247,091 | –432,939 |
| General health checkup | €91,712,390 | €54,738,639 | –36,973,751 |
| Colorectal cancer screening stool test | €4,252,667 | €3,234,019 | –1,018,648 |
| Colorectal cancer screening consultation | €7,279,721 | €8,850,274 | 1,570,553 |
| Colonoscopy | €17,697,434 | €13,365,208 | –4,332,226 |
| Skin cancer screening | €39,550,547 | €34,805,686 | –4,744,860 |
| Mammography screening | €31,707,309 | €29,193,370 | –2,513,940 |
of total screenings throughout the course of 2020, with the largest declines being temporally related to the lockdowns introduced in Germany. In addition to the largest change in perceived screenings in April 2020 (−52.34%), a decrease of about 24% was also noted in ambulatory care utilization for that month, as shown by Bayindir and Schreyögg (2022) (Bayindir and Schreyögg 2022). While ambulatory care utilization returned to prior-year levels during the year (Bayindir and Schreyögg 2022), no catch-up effects were detected in our study throughout the entire year.

The decline in utilization of cancer screenings shown in our study is consistent with international findings (Doubova et al. 2021; Lantinga et al. 2021; Mantellini et al. 2020; Song et al. 2021). For example, a systematic review by Alkatout et al. (2021) and a meta-analysis by Mayo et al. (2021) reported a substantial decline in screenings worldwide (Alkatout et al. 2021; Mayo et al. 2021). Compared to the existing literature, however, our study goes beyond examining only individual screenings by providing evidence on the development of screening utilization based on the analysis of the entire prevention program in Germany and differentiates between individual patient groups.

In addition, the change in utilization before and during COVID-19 developed differently for the individual preventive health services. The highest decrease was found in general health checkup with 45.35%, followed by declines in colorectal cancer screening stool test with 32.72%, skin cancer screening with 25.32%, and colonoscopy with 21.59%. Changes were less marked in the sex-specific screenings: mammography screening, general female cancer screening, and general male cancer screening with −11.33%, −9.87%, and −5.99% respectively. In contrast, colorectal cancer screening consultation, the only screening that does not involve a physical examination, increased by 8.92% in 2020. Consultation numbers as of June 2020 even surpassed the number of consultations for this screening compared to the same time period before COVID-19.

The overall negative development of patient numbers during the pandemic, both internationally and in Germany, as well as the different directions and magnitudes of changes in the utilization of the individual cancer screenings could have various causes: (1) A decrease in patient demand, which most likely is linked to the fear of an infection with SARS-CoV-2 (Hajek et al. 2021; Lazzerini et al. 2020). For example, a survey from the USA found that approximately 40.9% of respondents postponed or even avoided physician visits until June 2020 because they were concerned about COVID-19 (Czeisler et al. 2020). (2) A decrease in supply due to the suspension of services and programs, such as the interruption of breast cancer screening programs for different time periods in countries like Australia, the Netherlands, and the UK (Figueroa et al. 2021). Mammography screenings were also suspended in Germany at the beginning of the pandemic (Ärztezeitung 2020), which is reflected in our data set with a decrease of 98.71% in April 2020. At the same time, there is evidence that the likelihood of receiving appointments in outpatient practices in Germany decreased at the onset of the pandemic (Muschol and Gissel 2021), which may also have contributed to the change in case numbers for preventive health services.

(3) The different multiyear eligibility of each screening may have had an influence on utilization. For example, patients are only eligible for the general health checkup every three years, which could lead to the effect that this checkup might be more likely to be postponed by patients or physicians. (4) The respective medical procedure may have had an impact on utilization. Procedures such as skin cancer screenings or colonoscopies with pronounced physical contact and a presumably more time-consuming treatment have decreased, whereas colorectal cancer screening consultations that do not require intense physical contact have increased. In addition, the ability to perform these screenings with the help of video consultations might have also led to an increase in this type of screenings. (5) High utilization of screenings prior to the pandemic could be an indicator of the perceived relevance of the respective screenings, which persisted during the pandemic. In particular, general cancer screening for women, mammography screening, and general cancer screening for men were utilized comparatively frequently by eligible patients in 2019 with 46%, 25%, and 23%, respectively (Tillmanns et al. 2021).

**Decline for women and the elderly**

In addition to the general change in the utilization of individual screenings in Germany, our study also found that the utilization of screenings developed differently with regard to patient-specific characteristics such as sex and age. For screenings that can be claimed for both sexes, a significantly stronger decrease was observed for women than for men (32.94% vs. 30.03%). Structural changes in the population that occurred during the COVID-19 pandemic may have influenced utilization. For example, during the COVID-19 pandemic, the gender care gap was reflected in women having to perform more unpaid care work. This shift of time resources could have influenced women’s use of medical care (Pacheco et al. 2021; Power 2020).
Patients’ age also had a significant impact on screening utilization. The older the patients, the greater the decrease in utilization of screenings. While total screenings in 2020 decreased by 27.11% for those aged 40–59 years, the decrease was greatest among patients aged 80 years and older, at 42.49%. The decline in utilization might be related to the fact that older individuals are at increased risk for a severe COVID-19 progression and have an increased risk of mortality (Romero Starke et al. 2021). In addition, the elderly are often affected by health-care inequalities as they face access barriers to health-care systems and suffer from delays in medical care (Jang and Kim 2020; Saif-Ur-Rahman et al. 2021). The assumption that this effect may be exacerbated during the pandemic can be supported by our findings and leads to concerns that the health status of the elderly may deteriorate (Jang and Kim 2020).

Impact on policy and practice

Our results show that in an international comparison, a large number of state regulated preventive health services and screenings have not been performed in Germany either. The concern that cancer and other noncommunicable diseases, especially in early stages, are detected later also applies to Germany due to this trend. This circumstance could lead to a more severe disease progression and worse health outcomes for patients causing higher morbidity and mortality. This concern is supported for Germany by two studies from Jacob et al. (2021, 2022), which found that the number of cancer diagnoses decreased significantly in German practices during the COVID-19 pandemic (Jacob et al. 2021, 2022). For example, in April 2020, there were 32.0% fewer new cancer diagnoses in gynecology practices and 44.4% fewer in dermatology practices (Jacob et al. 2021).

Economic effects

Finally, our health economic analysis revealed that the change in utilization of preventive health services during COVID-19 also led to variations in outpatient reimbursement. Our calculation showed that approximately €55,558,823 were billed less during COVID-19. A WIdO report by Tillmanns et al. (2021) presented the 2019 and 2020 spending for preventive health services. These calculations showed a difference of around €49 million. Although the WIdO calculation considered more chargeable services and only took the years 2019 and 2020 into account, it resulted in similar overall differences, supporting our findings (Tillmanns et al. 2021). In the long term, however, these saved costs will most likely be offset by the costs arising from an increased burden and duration of diseases due to delayed or omitted early detection. First evidence of cancer treatment in Germany suggests considerable decreases in cancer diagnoses and cases such as skin cancer as well as gynecologic and breast cancer during the pandemic (Jacob et al. 2021, 2022; Kaltofen et al. 2022; Kleemann et al. 2022). The total amount of the additional costs caused by this development, however, will only be quantifiable in the future.

Practical implications

Our results show that individual screenings and patient groups underwent different shifts during the COVID-19 pandemic and that the utilization was particularly impaired among women and elderly patients. To be able to maintain public health in the long term and to be able to mitigate an increase in health-care spending, there are some practical implications in order to allocate limited medical resources in the best possible way. In the future, greater utilization of screenings should be promoted, and appropriate interventions have to be implemented by policymakers and health-care providers to support catch-up effects. Patients should be encouraged to continue using preventive health services and the safety of screenings should also be highlighted in the event of future unforeseeable developments.

Screenings that have seen the greatest decline in 2020, such as the general health checkup, colorectal cancer stool test, skin cancer screening, and colonoscopy, should be promoted the most. Furthermore, education on the utilization of cancer screening has to be tailored to individual groups of the population. In particular, access barriers for women and older patients need to be lowered and available resources should be targeted to these vulnerable groups. The use of digital applications could be promoted in the form of apps or telemedicine when suited for the respective examinations. During the COVID-19 pandemic, the use of telemedicine has increased in many areas, such as outpatient care in general medical practices or follow-up care of surgery patients, often providing satisfactory results (Knörr et al. 2022; Muschol et al. 2022). Some cancer screenings have also been supported by telehealth services (Price et al. 2022). One area that is particularly suitable for the use of telemedicine is dermatology (Trettel et al. 2018). For the screening of skin cancer, the use of artificial intelligence can also be beneficial (Sangers et al. 2021). Our study has shown that the COVID-19 related decrease in cancer screening utilization was strongly pronounced among older patients, i.e. they...
could be the population that benefits the most from digital health alternatives to conventional in-person screenings. When using digital health applications, it should therefore be ensured that older patients face no access barriers and that the applications are adapted to the needs and abilities of older people.

Finally, it is essential to continue monitoring the development of the utilization of screenings in the future, to timely recognize potential shifts in utilization for different patient groups, and to aim for timely reallocation of resources.

Limitations

This study has four main limitations. First, due to data protection, access to patient data is highly regulated for research in Germany. For this reason, the study was based on an aggregated data set and an analysis of individual factors was not possible. For example, no conclusions could be drawn about the socioeconomic status of patients, although this may have had an impact on the utilization of screenings and should therefore be investigated further in future studies. In addition, besides the COVID-19 pandemic, other factors could have had an impact on the utilization of screenings in 2020, which could not be determined within the scope of the study due to the data basis. However, we consider the strong influence of the COVID-19 pandemic to be the primary driver for the development of screening utilization. Second, because of the data structure, the annual number of eligible patients for the respective screenings could not be detected. In addition, it could be the case that individual patients changed age groups during the observation period. Because of the rather large data set, however, this should not have resulted in any major bias. Third, the retrospective study design only allowed for an analysis of the past screening utilization, which is why it was not possible to make statements about future developments in screenings and prognoses about the effect of omitted screenings on future development of cancer diagnoses and disease severity within the scope of the study. Finally, the data set included a vast number of the insured population in Germany. Nevertheless, not the entire population was represented within the data set and insurance-specific patient characteristics may differ from other insured patients, especially in private health insurances.

Conclusion

This was the first study that examined changes in the utilization of all preventive health services and cancer screenings available to SHI patients in Germany during the COVID-19 pandemic. Based on the analysis of claims data from the largest German statutory health insurance fund, it was found that the utilization of the individual screenings developed differently during the COVID-19 pandemic with an overall decline in utilization and no catch-up effects throughout 2020. This negative trend is also reflected in the international context. The patient groups of women and the elderly were particularly affected by the decline in cancer screenings. The postponement or omission of early detection of noncommunicable diseases is associated with the fear of worse health outcomes in the form of more severe disease progressions and increased mortality in the long term. At the same time, this could lead to increased health-care expenditures and a loss of productivity for the German economy. To counteract the negative trend, there is an urgent need for catch-up effects, especially for screenings, which have experienced a particularly severe reduction of utilization. To this end, resources should be targeted to encourage patients to make greater use of preventive health services and to support physicians in offering these services. To assist the delivery of screening in the future, the adoption of digital applications such as telemedicine, apps, or artificial intelligence should be expanded, as their increasing use since the onset of the pandemic has demonstrated their potential in this medical area. Only through focused collaboration between policymakers and health-care providers can the serious burdens that occurred during the COVID-19 pandemic and that extend beyond the direct impact of the pandemic be mitigated in the long term.
Appendix 1

See Fig. 3.

Fig. 3  Percentage change per individual screening during COVID-19 compared to before COVID-19
Appendix 2: Comparison of monthly utilization by women before and during COVID-19

| GOP | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | $\chi^2$ | df | p   | V   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|
| Total | 790,066 | 712,846 | 750,674 | 635,019 | 695,108 | 610,747 | 581,983 | 527,185 | 587,664 | 543,332 | 628,677 | 386,838 | 122,645 | 11 | < 0.001 | 0.096 |
| Before COVID-19 | 368,213 | 321,953 | 345,948 | 300,294 | 326,851 | 287,816 | 269,587 | 241,576 | 272,378 | 258,782 | 305,337 | 193,687 | |
| During COVID-19 | 350,615 | 298,934 | 257,862 | 177,870 | 261,730 | 290,600 | 276,434 | 212,374 | 288,067 | 263,247 | 288,355 | 181,750 | |
| Change (%) | – 17.05% | – 19.49% | – 38.25% | – 58.89% | – 33.59% | – 10.57% | – 5.73% | – 20.39% | – 5.03% | – 4.78% | – 13.98% | – 12.09% | |
| General female cancer screening | 5040 | 37,329 | 37,579 | 42,066 | 24,287 | 29,920 | 27,799 | 27,473 | 24,169 | 29,322 | 27,332 | 32,955 | 24,122 | 5040 | 11 | < 0.001 | 0.091 |
| GOP | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | $\chi^2$ | df | p  | V  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| During COVID-19 | 24,082 | 24,717 | 20,090 | 9941 | 17,572 | 20,672 | 23,014 | 15,416 | 22,952 | 21,960 | 22,794 | 16,833 |
| Change (%) | –35.49% | –34.23% | –52.24% | –59.07% | –41.27% | –25.64% | –16.23% | –36.21% | –21.72% | –19.65% | –30.83% | –30.22% |
| Colorectal cancer screening consultation | 31,564 | 28,790 | 30,730 | 28,659 | 32,615 | 28,848 | 30,967 | 28,313 | 31,129 | 30,752 | 34,520 | 21,929 |
| Before COVID-19 | 41,342 | 35,951 | 28,610 | 21,203 | 30,433 | 34,622 | 36,783 | 28,431 | 34,327 | 34,787 | 22,640 |
| Change (%) | +30.98% | +24.87% | –6.90% | –26.02% | –6.69% | +20.02% | +18.78% | +0.42% | +17.66% | +11.62% | +0.77% | +3.24% |
| Colonoscopy | 493 | 3770 | 4163 | 3670 | 3979 | 3775 | 3716 | 3561 | 3707 | 3568 | 4115 | 2827 |
| Before COVID-19 | 3644 | 3298 | 2834 | 1791 | 2505 | 2996 | 3202 | 2592 | 3407 | 2957 | 3113 | 2202 |
| Change (%) | –13.16% | –12.52% | –31.93% | –51.20% | –37.04% | –20.64% | –13.83% | –27.21% | –8.10% | –17.12% | –24.35% | –22.11% |
| Skin cancer screening | 111,886 | 102,099 | 104,556 | 94,092 | 102,637 | 89,993 | 89,663 | 79,867 | 85,730 | 76,615 | 86,628 | 53,870 |
| Before COVID-19 | 89,031 | 77,216 | 58,779 | 41,891 | 62,569 | 71,762 | 78,353 | 58,242 | 74,140 | 68,586 | 67,245 | 42,935 |
| Change (%) | –20.43% | –24.37% | –43.78% | –55.48% | –39.04% | –20.26% | –12.61% | –27.08% | –13.52% | –10.48% | –22.37% | –20.30% |
| Mammography screening | 49,629 | 49,381 | 40,918 | 41,998 | 46,292 | 43,590 | 40,055 | 41,751 | 46,981 | 48,113 | 53,484 | 25,253 |
| Before COVID-19 | 50,194 | 48,381 | 50,918 | 41,998 | 46,292 | 43,590 | 40,055 | 41,751 | 46,981 | 48,113 | 53,484 | 25,253 |
| Change (%) | +1.60% | +2.18% | –32.41% | –98.71% | –50.78% | +12.02% | +17.12% | +2.64% | +12.82% | +2.44% | –7.52% | +9.44% |
Appendix 3: Comparison of monthly utilization by men before and during COVID-19

| GOP | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov  | Dec  | χ²  | df | p      | V    |
|-----|------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|--------|------|
| Total | 425,778 | 374,249 | 375,127 | 307,686 | 325,943 | 284,328 | 276,626 | 253,928 | 276,376 | 255,370 | 301,741 | 200,072 | 42,598 | 11 | <0.001 | 0.081 |
| Before COVID-19 | 425,778 | 374,249 | 375,127 | 307,686 | 325,943 | 284,328 | 276,626 | 253,928 | 276,376 | 255,370 | 301,741 | 200,072 |  | | | |
| During COVID-19 | 333,208 | 288,463 | 226,261 | 156,461 | 217,022 | 241,157 | 250,868 | 194,515 | 250,327 | 235,632 | 245,009 | 166,993 |  | | | |
| Change (%) | -21.74% | -22.92% | -39.68% | -49.15% | -33.42% | -15.18% | -9.31% | -23.40% | -9.43% | -7.73% | -18.80% | -16.53% |  | | | |
| General male cancer screening | 10,208 | 11 | <0.001 | 0.072 |  | | | | | | | | 10,208 | 11 | <0.001 | 0.072 |
| Before COVID-19 | 115,109 | 100,819 | 104,417 | 86,940 | 90,377 | 78,537 | 73,672 | 68,792 | 75,677 | 76,624 | 94,064 | 62,328 |  | | | |
| During COVID-19 | 115,458 | 99,903 | 81,800 | 55,984 | 76,537 | 83,474 | 80,437 | 64,102 | 83,665 | 79,455 | 87,148 | 57,889 |  | | | |
| Change (%) | +0.30% | -0.91% | -21.66% | -35.61% | -15.31% | +6.29% | +9.18% | -6.82% | +10.55% | +3.70% | -7.35% | -7.12% | | | | |
| General health checkup | 24,768 | 11 | <0.001 | 0.113 |  | | | | | | | | 24,768 | 11 | <0.001 | 0.113 |
| Before COVID-19 | 157,253 | 137,147 | 134,919 | 107,163 | 112,966 | 97,077 | 91,322 | 83,517 | 91,678 | 76,652 | 89,533 | 57,483 |  | | | |
| During COVID-19 | 84,842 | 72,244 | 52,844 | 35,096 | 51,933 | 59,477 | 63,691 | 48,072 | 62,998 | 60,241 | 60,972 | 41,068 |  | | | |
| Change (%) | -46.05% | -47.32% | -60.83% | -67.25% | -54.03% | -38.73% | -30.26% | -42.44% | -31.28% | -21.41% | -31.90% | -28.56% |  | | | |
| Colorectal cancer screening stool test | 2737 | 11 | <0.001 | 0.086 |  | | | | | | | | 2737 | 11 | <0.001 | 0.086 |
| Before COVID-19 | 26,174 | 24,658 | 24,820 | 15,267 | 17,275 | 15,364 | 16,171 | 14,593 | 16,103 | 16,226 | 19,286 | 13,036 |  | | | |
| During COVID-19 | 17,190 | 16,544 | 12,621 | 7446 | 11,501 | 12,660 | 14,670 | 10,419 | 13,596 | 13,154 | 13,161 | 9473 |  | | | |
| Change (%) | -34.32% | -32.91% | -49.15% | -51.23% | -33.42% | -17.60% | -9.28% | -28.60% | -15.57% | -18.93% | -31.76% | -27.33% |  | | | |
| GOP                        | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | \( \chi^2 \) | df | \( p \) | \( V \) |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------------|----|--------|------|
| **Colorectal cancer screening consultation** |     |     |     |     |     |     |     |     |     |     |     |     | 2191        | 11 | <0.001 | 0.061 |
| Before COVID-19            | 26,494 | 23,628 | 23,936 | 22,363 | 24,732 | 21,821 | 23,679 | 22,162 | 23,439 | 23,392 | 26,388 | 18,002 |     |     |     |
| During COVID-19            | 34,326 | 30,185 | 24,761 | 18,711 | 23,795 | 26,519 | 28,395 | 22,958 | 28,355 | 26,164 | 26,966 | 18,934 |     |     |     |
| Change (%)                 | + 29.56% | + 27.75% | + 3.45% | - 16.33% | - 3.79% | + 21.53% | + 19.91% | + 3.59% | + 20.97% | + 11.85% | + 2.19% | + 5.18% |     |     |     |
| **Colonoscopy**            |     |     |     |     |     |     |     |     |     |     |     |     | 260         | 11 | <0.001 | 0.060 |
| Before COVID-19            | 3857 | 3575 | 3813 | 3301 | 3583 | 3266 | 3297 | 3150 | 3257 | 3084 | 3519 | 2592 |     |     |     |
| During COVID-19            | 3417 | 3042 | 2831 | 1903 | 2495 | 2791 | 2952 | 2448 | 2984 | 2679 | 2742 | 2094 |     |     |     |
| Change (%)                 | - 11.42% | - 14.91% | - 25.75% | - 42.34% | - 30.36% | - 14.54% | - 10.47% | - 22.29% | - 8.38% | - 13.14% | - 22.08% | - 19.20% |     |     |     |
| **Skin cancer screening**  |     |     |     |     |     |     |     |     |     |     |     |     | 8711        | 11 | <0.001 | 0.076 |
| Before COVID-19            | 96,891 | 84,422 | 83,222 | 72,654 | 77,010 | 68,263 | 68,485 | 61,714 | 66,222 | 59,391 | 68,950 | 46,631 |     |     |     |
| During COVID-19            | 77,975 | 66,545 | 51,404 | 37,321 | 50,761 | 56,236 | 60,723 | 46,516 | 58,729 | 53,939 | 54,020 | 37,535 |     |     |     |
| Change (%)                 | - 19.52% | - 21.18% | - 38.23% | - 48.63% | - 34.09% | - 17.62% | - 11.33% | - 24.63% | - 11.31% | - 9.18% | - 21.65% | - 19.51% |     |     |     |
Appendix 4: Comparison of female utilization between age categories before and during COVID-19

| GOP                        | 25–39 years | 40–59 years | 60–79 years | > 80 years | $\chi^2$ | df | p     | V  |
|----------------------------|-------------|-------------|-------------|------------|---------|-----|-------|-----|
| Total screenings           |             |             |             |            | 49,935  | 3   | <0.001| 0.061|
| Before COVID-19            | 1,149,367   | 2,864,384   | 2,658,900   | 777,489    |          |     |       |     |
| During COVID-19            | 1,096,952   | 2,356,907   | 2,007,544   | 456,670    |          |     |       |     |
| Change (%)                 | –4.56%      | –17.72%     | –24.50%     | –41.26%    |          |     |       |     |
| General female cancer screening |           |             |             |            |     |     |       |     |
| Before COVID-19            | 1,149,367   | 1,350,438   | 814,114     | 178,503    |          |     | <0.001| 0.036|
| During COVID-19            | 1,096,952   | 1,231,165   | 699,064     | 120,657    |          |     |       |     |
| Change (%)                 | –4.56%      | –8.83%      | –14.13%     | –32.41%    |          |     |       |     |
| General health checkup    |             |             |             |            | 8808    | 3   | <0.001| 0.051|
| Before COVID-19            | 646,276     | 630,480     | 298,102     | 312,838    |          |     |       |     |
| During COVID-19            | 385,588     | 324,562     | 132,838     |          |          |     |       |     |
| Change (%)                 | –40.34%     | –48.52%     | –55.44%     |            |          |     |       |     |
| Colorectal cancer screening stool test |     |             |             |            | 1465    | 2   | <0.001| 0.049|
| Before COVID-19            | 110,355     | 198,460     | 55,537      |            |          |     |       |     |
| During COVID-19            | 65,387      | 142,682     | 31,974      |            |          |     |       |     |
| Change (%)                 | –40.75%     | –28.11%     | –42.43%     |            |          |     |       |     |
| Colorectal cancer screening consultation |     |             |             |            | 4001    | 2   | <0.001| 0.073|
| Before COVID-19            | 111,979     | 192,864     | 53,973      |            |          |     |       |     |
| During COVID-19            | 146,618     | 190,884     | 48,252      |            |          |     |       |     |
| Change (%)                 | +30.93%     | –1.03%      | –10.60%     |            |          |     |       |     |
| Colonoscopy                |             |             |             |            | 505     | 1   | <0.001| 0.080|
| Before COVID-19            | 40,341      | 4707        |            |            |          |     |       |     |
| During COVID-19            | 32,481      | 2060        |            |            |          |     |       |     |
| Change (%)                 | –19.48%     | –56.24%     |            |            |          |     |       |     |
| Skin cancer screening      |             |             |             |            | 1629    | 2   | <0.001| 0.030|
| Before COVID-19            | 450,060     | 440,908     | 186,667     |            |          |     |       |     |
| During COVID-19            | 347,037     | 322,823     | 120,889     |            |          |     |       |     |
| Change (%)                 | –22.89%     | –26.78%     | –35.24%     |            |          |     |       |     |
| Mammography screening      |             |             |             |            | 302     | 1   | <0.001| 0.017|
| Before COVID-19            | 195,276     | 341,734     |            |            |          |     |       |     |
| During COVID-19            | 181,112     | 295,048     |            |            |          |     |       |     |
### Appendix 5: Comparison of male utilization between age categories before and during COVID-19

| GOP                        | 25–39 years | 40–59 years | 60–79 years | > 80 years | \( \chi^2 \) | df | p   | V  |
|----------------------------|-------------|-------------|-------------|------------|-------------|----|-----|----|
| Change (%)                 | –7.25%      | –13.66%     |             |            |             |    |     |    |

*Data from patients ≥ 55 years*

### Changes in Male Cancer Screening Utilization

#### Total screenings

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| Total screenings | 1,299,341       | 2,385,013       | –20.70%    | 3435        | 2  | <0.001 | 0.023 |

#### General male cancer screening

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| General male cancer screening | 567,556         | 390,469         | –31.20%    | 1710        | 2  | <0.001 | 0.029 |

#### General health checkup

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| General health checkup | 210,657         | 176,731         | –16.10%    | 5745        | 2  | <0.001 | 0.055 |

#### Colorectal cancer screening stool test

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| Colorectal cancer screening stool test | 38,808           | 23,063          | –40.57%    | 436        | 2  | <0.001 | 0.034 |

#### Colonoscopy

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| Colonoscopy    | 36,305          | 30,466          | –16.08%    | 384        | 1  | <0.001 | 0.073 |

#### Skin cancer screening

|                | Before COVID-19 | During COVID-19 | Change (%) | \( \chi^2 \) | df | p   | V  |
|----------------|-----------------|-----------------|------------|-------------|----|-----|----|
| Skin cancer screening | 116,545         | 1912            | –52.06%    | 674        | 2  | <0.001 | 0.021 |
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Declarations

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