

10-year prevalence of diagnostic and screening colonoscopy use in Germany: a claims data analysis

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Introduction Studies providing detailed information on colonoscopy use are important for the interpretation of patterns and trends in colorectal cancer incidence and mortality, but there is a lack of such studies from Germany. To fill this gap, we aimed to describe the 10-year prevalence of colonoscopy use based on German health claims data.

Methods Using the German Pharmacoepidemiological Research Database (short GePaRD; claims data from ~20% of the German population), we determined the 10-year prevalence of colonoscopy use for the year 2017. We determined this prevalence for any colonoscopy, screening (reimbursable from age 55) and diagnostic colonoscopy, stratified by sex, age, educational level and regional factors (e.g. federal state, physicians density in the district of residence).

Results In men, the 10-year prevalence of colonoscopy use was as follows (not all age groups reported): 30–34 years: 8%, 40–44 years: 12%, 50–54 years: 21%, 55–59 years: 33% (screening: 10%), 60–64 years: 44% (screening: 23%), 70–74 years: 53% (screening: 23%), 80–84 years: 52% (screening: 15%). In women, the prevalences were similar, with differences mostly less than

or equal to 3 percentage points. Also, in analyses stratified by educational level or regional factors, prevalences were mostly similar or varied by less than or equal to 4 percentage points.

Conclusion In 2017, about 45–50% of men and women in Germany aged 60–84 years had any colonoscopy in the previous 10 years, and about 11–26% had a screening colonoscopy. Our findings suggest no relevant social or regional disparities in the utilization of colonoscopy in Germany. *European Journal of Cancer Prevention* 31: 497–504 Copyright © 2022 The Author(s). Published by Wolters Kluwer Health, Inc.

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Introduction

Colorectal cancer (CRC) is the second most common cancer and the cause of cancer-related death in Europe (Ferlay *et al.*, 2018). Within Europe, there are marked differences regarding current levels as well as recent trends in CRC incidence and mortality. In 2020, estimated age-standardized CRC incidence (per 100.000) was, for example, 21.0 in Austria, 35.8 in Spain and 41.9 in Norway; and age-standardized CRC mortality (per 100.000) was 8.8 in Finland, 13.0 in Portugal and 21.0 in Slovakia (Ferlay *et al.*, 2020). Germany is one of the few countries where not only CRC mortality, but also CRC incidence has started to decline in recent years. Between 2000 and 2016, age-standardized CRC incidence decreased by 22% in men and 26% in women,

and age-standardized CRC mortality decreased by 36% in men and 41% in women between 2000 and 2018 (Cardoso *et al.*, 2021). In Germany, screening colonoscopy has been offered since 2002 as part of an opportunistic screening programme to persons aged 55 or older as an alternative to the faecal occult blood test offered from age 50 onwards (Haug, 2018). An organized CRC screening programme has been introduced in 2019 (Gemeinsamer Bundesausschuss, 2020).

While changes in the prevalence of CRC risk factors may also be important, there is a general consensus that colonoscopy use plays an important role regarding trends in CRC incidence and mortality given the convincing evidence on the effectiveness of lower endoscopy in preventing CRC and CRC-related death (Lauby-Secretan *et al.*, 2018). High-quality information on the prevalence of colonoscopy use at the population level is thus important for understanding recent and projecting future trends in CRC incidence and mortality. Such information is also useful to detect potential subgroups of the population with low use of colonoscopy who may be targeted for educational interventions. Ideally, data to determine the

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prevalence of colonoscopy use would not only capture screening colonoscopies but also – as a separate category – diagnostic colonoscopies given that both are expected to exert a preventive effect (Brenner *et al.*, 2014). Furthermore, longitudinal data with a sufficiently long observation period are required in view of the long-lasting effect of colonoscopy. 10-year prevalence is a reasonable measure and more informative as compared to prevalences determined for shorter time periods. Finally, given that many risk factors of CRC have been reported to be correlated with a low socioeconomic status (SES) (Doubeni *et al.*, 2012), determining the prevalence of colonoscopy use stratified by SES would also provide important insights. Even though there have been reports on colonoscopy use in Germany (Altenhofen; Stock *et al.*, 2010, 2011; Starker and Saß, 2013; Altenhofen, 2016; Chen *et al.*, 2017; Starker *et al.*, 2017; Cardoso *et al.*, 2019; Chen *et al.*, 2019b; Tillmanns *et al.*, 2019; Cardoso *et al.*, 2020; Guo *et al.*, 2020; Steffen *et al.*, 2020), there is – to the best of our knowledge – no study from Germany doing justice to all aspects mentioned above.

To overcome this gap, we aimed to use the potential of the German Pharmacoepidemiological Research Database (GePaRD), a large claims database, to determine 10-year prevalence of colonoscopy use for the year 2017, stratified by screening vs. diagnostic colonoscopy, age, sex, estimates of the SES and regional factors.

Methods

Data source

This study was conducted using GePaRD which is based on claims data from four statutory health insurance providers in Germany and currently includes information on approximately 25 million persons who have been insured with one of the participating providers since 2004 or later. In addition to the demographic data, GePaRD contains information on drug dispensations as well as outpatient (i.e. from general practitioners and specialists) and inpatient services and diagnoses. Per data year, there is information on approximately 20% of the general population and all geographical regions of Germany are represented.

In GePaRD, information on colonoscopy use, including the date of the procedure, is obtained based on codes of the German Uniform Assessment Standard (EBM) and the Operations and Procedures Coding System (OPS). There are different codes for screening and diagnostic colonoscopy, that is, these two types of colonoscopy can be distinguished.

In Germany, the utilization of health insurance data for scientific research is regulated by the Code of Social Law. All involved health insurance providers as well as the German Federal Office for Social Security and the Senator for Health, Women and Consumer Protection

in Bremen as their responsible authorities approved the use of GePaRD data for this study. Informed consent for studies based on claims data is required by law unless obtaining consent appears unacceptable and would bias results, which was the case in this study. According to the Ethics Committee of the University of Bremen, studies based on GePaRD are exempt from institutional review board review.

Study design and study population

To determine 10-year prevalence for the year 2017, we included all persons with valid information on sex and age, place of residence in Germany and a continuous insurance period from at least 2006 to 2017 (denominator). Among these, we determined the number of persons who had at least one colonoscopy between 2008 and 2017 (numerator) and calculated the 10-year prevalence of colonoscopy use for the year 2017. If a person had both a screening and a diagnostic colonoscopy in this 10-year time period, we used the first examination to classify persons into screening vs. diagnostic colonoscopy use. We used a pre-observation period of 2 years to assess whether the persons with a colonoscopy already had any codes indicating a prevalent CRC before colonoscopy. For example, for persons with a colonoscopy in 2008, we used the data from 2006 and 2007 as pre-observation period regarding prevalent CRC. For comparison, we also calculated the 5-year prevalence of colonoscopy use for 2017 in an analogous way.

Data analysis

We characterized included men and women (denominator) with respect to the distribution of age, SES (two categories defined by educational level) and region of residence. Similarly, we described 10-year prevalence of colonoscopy use in men and women with respect to these factors, both for colonoscopy overall and stratified by type of the first colonoscopy (screening vs. diagnostic). With respect to regional factors, we considered federal state, geographical region (Northern, Western, Southern or Eastern Germany), urbanization of the district of residence (urban vs. rural) (Bundesinstitut für Bau- Stadt- und Raumforschung, 2020) as well as density of physicians (any physician, gastroenterologists) in the respective district of residence (Statistisches Bundesamt, 2021).

We calculated 95% confidence intervals (CIs) of colonoscopy prevalence using the Wald method. The analyses were carried out with the statistical software SAS 9.4 (SAS Institute, Inc., Cary, North Carolina, USA).

Results

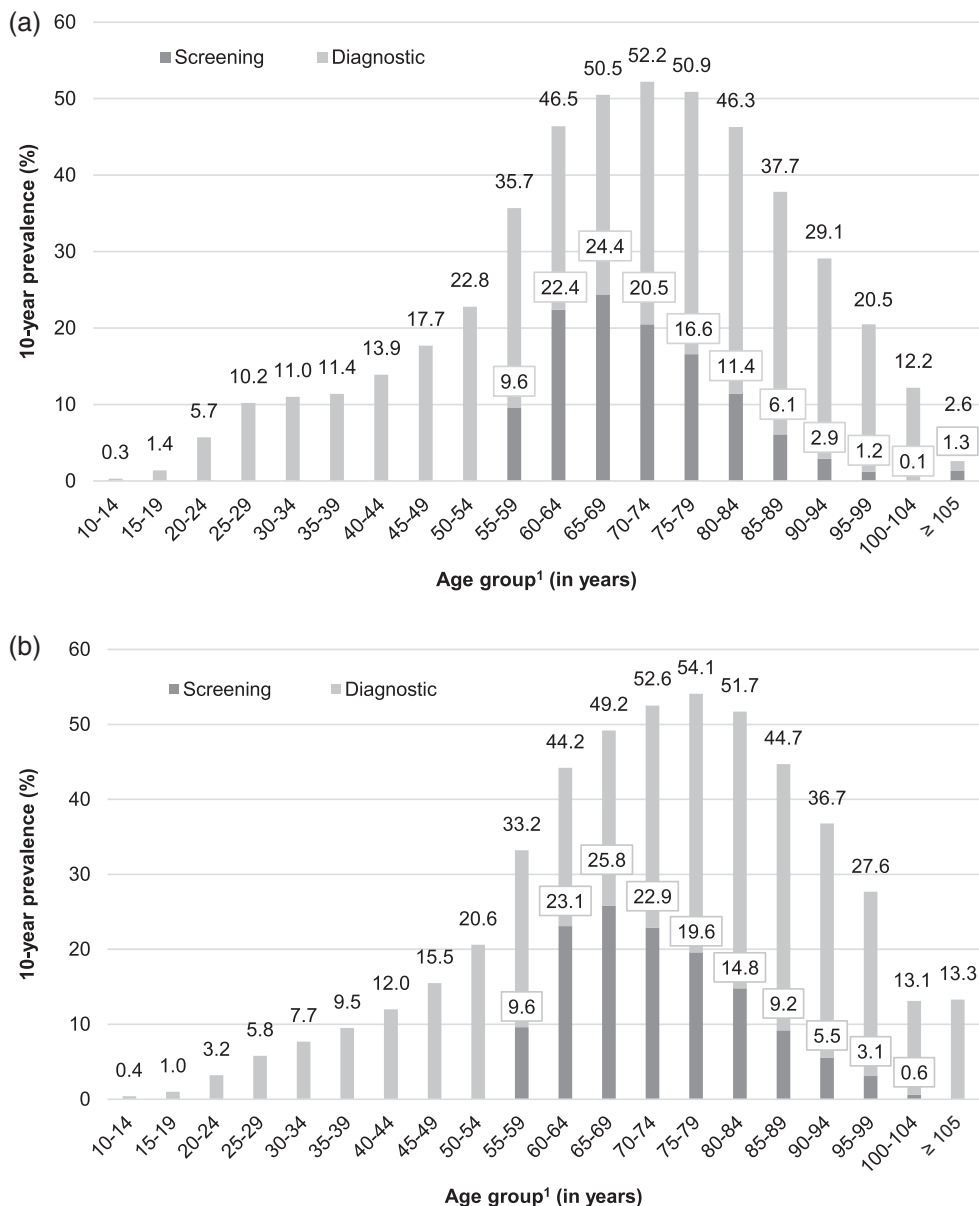
Overall, a total of 7 475 668 persons (55% female) were included. Of these, 2 287 472 had at least one colonoscopy between 2008 and 2017, yielding a 10-year prevalence of

colonoscopy use of 31% overall (diagnostic colonoscopy: 21%, screening colonoscopy: 10%).

As shown in Fig. 1a (women) and Fig. 1b (men), the 10-year prevalence of colonoscopy varied by age. In women, the overall 10-year prevalence increased from 10% at age 25–44 to 23% at age 50–54 and was 36% at age 55–59. At age 65–79 it was highest with a 10-year prevalence of 51–52% and it remained above 35% until age 85–89. In men, the age pattern regarding the overall 10-year prevalence of colonoscopy was similar, with some minor differences in younger and older adults: Below

age 65, the prevalence was up to 2–4 percentage points lower and from the ages 75–79 to 95–99, the prevalence was 3–8 percentage points higher as compared to women. The 10-year prevalence of screening colonoscopy in men and women was 10% at age 55–59 and 22–26% at age 60–69. It started to decline thereafter: in women from 21% (men: 23%) at age 70–74 to 6% (men: 9%) at age 85–89 (see also Supplemental digital content 1, <http://links.lww.com/EJCP/A348>, showing sample sizes and CIs). The 5-year prevalence showed patterns similar to the 10-year prevalence. In almost all age and sex groups, it

Fig. 1



(a) 10-year prevalence of colonoscopy use (screening and diagnostic) among women in 2017 according to age. (b) 10-year prevalence of colonoscopy use (screening and diagnostic) among men in 2017 according to age. ¹Age in 2017.

was more than half as high as the 10-year prevalence; at age 55–59, it amounted to 76% of the 10-year prevalence (see Supplemental digital content 2, <http://links.lww.com/EJCP/A348>).

Table 1 shows the 10-year prevalence of screening and diagnostic colonoscopy use in 2017 according to SES in men and women, stratified by age (≤ 65 vs. >65 years). Regarding SES, the 10-year prevalence of screening colonoscopy was 4 percentage points lower among men above age 65 with a (basic) secondary degree as compared to those with a higher educational degree (24.1 vs. 28.1%). In women less than or equal to 65 years, the 10-year prevalence of colonoscopy overall was 4.6 percentage points higher among those with a (basic) secondary degree as compared to those with a higher educational degree (24.1 vs. 19.5%). In all other subgroups, the difference in the prevalence of screening or diagnostic colonoscopy according to educational level was below 3 percentage points.

Table 2 shows the 10-year prevalence of colonoscopy use – overall, screening and diagnostic – in 2017 according to federal state and other regional factors, stratified by age (≤ 65 vs. >65 years). Among persons aged less than or equal to 65 years, the prevalence of overall colonoscopy use ranged from 18% (minimum) in Saxony to 22–23% (maximum) in Hesse, Rhineland-Palatinate, Baden-Württemberg, Bavaria, Saarland and Mecklenburg-Western Pomerania. Among persons aged greater than 65 years, the prevalence of overall colonoscopy use was 46–47% in Bremen, North Rhine-Westphalia, Saarland, Saxony-Anhalt and Thuringia, 48–49% in Saxony and Brandenburg and 50–52% in all other federal states. The 10-year prevalence of screening colonoscopy tended to be higher in federal states with a lower prevalence of diagnostic colonoscopy and vice versa (e.g. Hesse and Brandenburg). When grouping the federal states into

Northern, Southern, Eastern and Western Germany, the prevalence of colonoscopy use overall ranged from 19% (Eastern Germany) to 23% (Southern Germany) in persons aged less than or equal to 65 years and from 47% (Eastern Germany) to 51% (Southern Germany) in persons aged greater than 65 years. In persons aged greater than 65 years, the prevalence of screening colonoscopy was higher in the Northern (21%) than in the Western part of Germany (15%) but for diagnostic colonoscopy, it was inverse (Western: 34%; Northern: 29%). Stratification by urbanization of the district of residence (urban vs. rural) did not show any differences in the prevalence of colonoscopy use, neither in persons less than or equal to 65 years nor in persons aged greater than 65 years. Also, the 10-year prevalence did not vary when we distinguished between federal states with a high vs. a low density of physicians (any kind) or gastroenterologists.

The proportion of persons with colonoscopy with codes indicating the presence of prevalent CRC in the 2 years before colonoscopy was 3% overall (screening: 2%, diagnostic: 4%). It increased with age, from below 3% in persons aged less than 65 years to 5% in persons aged 75–79 and it was 7% in persons aged greater than or equal to 80 years (see Supplemental digital content 3, <http://links.lww.com/EJCP/A348>). In Supplemental digital content 4, <http://links.lww.com/EJCP/A348>, the prevalence of codes for relevant diagnoses, symptoms or other conditions recorded in persons before diagnostic colonoscopy is shown, which may reflect potential reasons for diagnostic colonoscopies.

Discussion

To the best of our knowledge, this is the most comprehensive study investigating the 10-year prevalence of colonoscopy use in Germany based on claims data, with

Table 1 10-year prevalence of colonoscopy use (overall, screening and diagnostic) in 2017 according to educational level in women and men aged ≤ 65 and >65 years

	Age ≤ 65 years ^a			Age >65 years ^a		
	Overall	Type of colonoscopy		Overall	Type of colonoscopy	
		Screening	Diagnostic		Screening	Diagnostic
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Women						
Total	22.7 (22.6–22.7)	5.5 (5.5–5.5)	17.2 (17.1–17.2)	48.0 (47.9–48.0)	16.2 (16.2–16.3)	31.7 (31.7–31.8)
Educational level ^b						
(Basic) secondary degree	24.1 (24.1–24.2)	6.0 (6.0–6.1)	18.1 (18.1–18.2)	51.0 (50.8–51.3)	24.5 (24.3–24.8)	26.5 (26.3–26.8)
Higher education	19.5 (19.5–19.6)	4.3 (4.3–4.3)	15.2 (15.2–15.3)	52.2 (51.8–52.6)	26.4 (26.0–26.8)	25.8 (25.4–26.2)
Men						
Total	19.6 (19.6–19.7)	5.3 (5.3–5.4)	14.3 (14.2–14.3)	51.2 (51.1–51.3)	19.7 (19.6–19.7)	31.5 (31.5–31.6)
Educational level ^b						
(Basic) secondary degree	17.2 (17.1–17.2)	4.3 (4.3–4.4)	12.8 (12.8–12.9)	50.5 (50.3–50.8)	24.1 (23.8–24.3)	26.5 (26.2–26.7)
Higher education	20.1 (20.0–20.2)	5.6 (5.6–5.7)	14.5 (14.4–14.6)	53.7 (53.4–53.9)	28.1 (27.8–28.3)	25.6 (25.4–25.8)

CI, confidence interval.

^aAge in 2017.

^bCategory degree unknown/no formal degree not shown here.

Table 2 10-year prevalence of colonoscopy use (overall, screening and diagnostic) in 2017 according to federal state and other regional factors in persons aged ≤65 and >65 years

	Age ≤65 years ^a			Age >65 years ^a		
	Overall	Type of colonoscopy		Overall	Type of colonoscopy	
		Screening	Diagnostic		Screening	Diagnostic
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Federal state						
Schleswig-Holstein	20.2 (20.1–20.4)	5.9 (5.8–6.0)	14.3 (14.2–14.5)	49.7 (49.4–50.0)	21.1 (20.9–21.3)	28.6 (28.3–28.8)
Hamburg	21.0 (20.8–21.2)	6.0 (5.9–6.1)	15.0 (14.9–15.2)	52.3 (51.9–52.6)	26.1 (25.8–26.4)	26.2 (25.9–26.5)
Lower Saxony	21.2 (21.1–21.3)	6.3 (6.2–6.4)	14.9 (14.8–15.0)	49.7 (49.5–49.8)	20.9 (20.8–21.1)	28.7 (28.6–28.9)
Bremen	20.6 (20.3–20.8)	5.3 (5.2–5.4)	15.3 (15.1–15.5)	47.0 (46.7–47.4)	17.4 (17.1–17.6)	29.7 (29.3–30.0)
North Rhine-Westphalia	20.5 (20.5–20.6)	5.1 (5.0–5.1)	15.5 (15.4–15.5)	47.3 (47.2–47.5)	15.4 (15.3–15.5)	31.9 (31.8–32.0)
Hesse	21.8 (21.7–21.9)	3.7 (3.6–3.7)	18.1 (18.0–18.2)	49.6 (49.4–49.8)	12.0 (11.8–12.1)	37.6 (37.4–37.8)
Rhineland-Palatinate	23.0 (22.8–23.2)	5.4 (5.3–5.5)	17.6 (17.4–17.7)	49.8 (49.5–50.1)	16.1 (15.9–16.3)	33.7 (33.4–34.0)
Baden-Wuerttemberg	22.2 (22.1–22.3)	5.8 (5.7–5.8)	16.4 (16.3–16.5)	50.4 (50.2–50.6)	17.2 (17.1–17.4)	33.2 (33.0–33.3)
Bavaria	23.1 (23.0–23.2)	5.0 (5.0–5.1)	18.1 (18.0–18.2)	51.6 (51.4–51.8)	17.4 (17.2–17.5)	34.2 (34.1–34.4)
Saarland	22.8 (22.4–23.1)	5.8 (5.6–6.0)	17.0 (16.7–17.3)	47.3 (46.7–47.9)	17.2 (16.7–17.6)	30.2 (29.6–30.7)
Berlin	18.9 (18.8–19.0)	5.6 (5.5–5.7)	13.3 (13.2–13.4)	51.5 (51.2–51.8)	23.1 (22.8–23.3)	28.5 (28.2–28.8)
Brandenburg	19.8 (19.6–20.0)	7.0 (6.9–7.1)	12.8 (12.6–12.9)	48.8 (48.5–49.1)	22.1 (21.8–22.3)	26.8 (26.5–27.1)
Mecklenburg-Western Pomerania	22.0 (21.8–22.3)	6.6 (6.4–6.7)	15.4 (15.2–15.7)	50.8 (50.4–51.2)	17.3 (17.0–17.6)	33.6 (33.2–33.9)
Saxony	18.2 (18.0–18.4)	5.8 (5.7–5.9)	12.4 (12.2–12.6)	47.9 (47.5–48.2)	19.8 (19.5–20.1)	28.1 (27.8–28.4)
Saxony-Anhalt	19.7 (19.4–20.0)	6.0 (5.8–6.2)	13.7 (13.5–13.9)	46.2 (45.7–46.6)	17.5 (17.1–17.8)	28.7 (28.3–29.1)
Thuringia	20.5 (20.2–20.7)	6.0 (5.8–6.1)	14.5 (14.2–14.7)	45.7 (45.3–46.1)	16.7 (16.4–17.0)	29.0 (28.6–29.4)
Geographical region^b						
North	20.5 (20.4–20.6)	6.1 (6.1–6.1)	14.4 (14.3–14.4)	49.9 (49.8–50.0)	21.2 (21.1–21.3)	28.7 (28.6–28.8)
South	22.7 (22.6–22.8)	5.4 (5.3–5.4)	17.3 (17.3–17.4)	51.0 (50.9–51.1)	17.3 (17.2–17.4)	33.7 (33.6–33.8)
East	19.3 (19.1–19.4)	5.9 (5.8–6.0)	13.4 (13.3–13.5)	46.8 (46.5–47.0)	18.2 (18.1–18.4)	28.5 (28.3–28.7)
West	21.3 (21.2–21.3)	4.8 (4.8–4.9)	16.4 (16.4–16.5)	48.3 (48.1–48.4)	14.8 (14.7–14.8)	33.5 (33.4–33.6)
Urbanization of district of residence						
Urban	21.2 (21.1–21.2)	5.3 (5.3–5.3)	15.9 (15.8–15.9)	49.7 (49.6–49.8)	17.7 (17.6–17.7)	32.0 (32.0–32.1)
Rural	21.5 (21.4–21.5)	5.7 (5.7–5.8)	15.8 (15.7–15.8)	48.5 (48.4–48.6)	17.7 (17.7–17.8)	30.7 (30.6–30.8)
Density of physicians						
Low ^c	21.4 (21.4–21.5)	5.5 (5.5–5.6)	15.9 (15.8–15.9)	49.3 (49.3–49.4)	17.5 (17.4–17.6)	31.8 (31.8–31.9)
High ^d	21.1 (21.1–21.2)	5.3 (5.3–5.4)	15.8 (15.7–15.8)	49.4 (49.3–49.4)	17.9 (17.8–17.9)	31.5 (31.4–31.6)
Density of gastroenterologists						
Low ^e	21.3 (21.3–21.4)	5.4 (5.4–5.4)	15.9 (15.9–16.0)	49.4 (49.3–49.5)	17.3 (17.3–17.4)	32.1 (32.0–32.2)
High ^f	21.2 (21.1–21.2)	5.5 (5.5–5.5)	15.7 (15.6–15.7)	49.3 (49.2–49.4)	18.3 (18.2–18.4)	31.0 (30.9–31.1)

CI, confidence interval.

^aAge in 2017.^bNorth: Schleswig-Holstein, Hamburg, Lower Saxony, Bremen, Berlin, Brandenburg, Mecklenburg-Western Pomerania; South: Baden-Wuerttemberg, Bayern; East: Saxony, Saxony-Anhalt, Thuringia; West: North Rhine-Westphalia, Hesse, Rhineland-Palatinate, Saarland.^cFederal states with low density of physicians: Baden-Wuerttemberg, Brandenburg, Hesse, Lower Saxony, Rhineland-Palatinate, Saxony, Saxony-Anhalt, Thuringia.^dFederal states with high density of physicians: Bavaria, Berlin, Bremen, Hamburg, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Saarland, Schleswig-Holstein.^eFederal states with low density of gastroenterologists: Baden-Wuerttemberg, Bavaria, Berlin, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Saarland, Schleswig-Holstein, Thuringia.^fFederal states with high density of gastroenterologists: Brandenburg, Bremen, Hamburg, Hesse, Lower Saxony, Rhineland-Palatinate, Saxony, Saxony-Anhalt.

a sample size facilitating a detailed description of colonoscopy use by age, sex, estimates of SES and regional factors. The 10-year prevalence of colonoscopy increased from ~20% at age 50–54, to ~30% at age 55–59 and ~45–50% at age 60–84. Also, in persons aged 85–94, the prevalence remained at levels of ~30–40%. Screening colonoscopy accounted for ~40–50% of the 10-year prevalence in persons aged 60–74, whereas in most other age groups eligible for screening, it had a share of one-third or less. Overall, the patterns in 10-year prevalence by age and type of colonoscopy were rather similar in men and women. Women tended to show a slightly higher prevalence regarding overall colonoscopy use compared to men below the age of 55 (maximum difference 4.4 percentage points) whereas it tended to be lower above the age of 74 (maximum difference 7.6 percentage points).

There were no relevant differences in the overall 10-year prevalence according to levels of SES or regional factors such as the density of physicians and gastroenterologists in the district of residence.

The 10-year prevalence of overall and screening colonoscopy use observed in our study is in line with findings presented in a report based on data from 2006 to 2017 from a large statutory health insurance provider not included in our study. Nonetheless, the maximum level of 10-year prevalence mentioned in that report (44% at age 65–75) is somewhat lower than the maximum levels observed in our study (~50%) suggesting minor differences between statutory health insurance providers in Germany. A detailed comparison to our study, however, is not possible as both the methodology and the results in that report were only described roughly and there was

no stratification by sex or other factors (Tillmanns *et al.*, 2019). There was one further study based on German claims data describing 10-year prevalence of colonoscopy use but the sample size was small ($n = 108\,225$); the data are old (data from 2000 to 2008) and they did not cover a 10-year period, so extrapolation was needed (Stock *et al.*, 2011). Studies based on survey data from Germany reported 10-year prevalences even higher than our study. For example, two studies using national health survey data reported a 10-year prevalence of 55% among persons greater than or equal to 55 years in 2008–2011 and of 59% in 2014–2015 (Starker and Saß, 2013; Starker *et al.*, 2017). The higher estimates compared to claims data-based findings may be explained by recall bias. In a study by Hoffmeister *et al.* (2007), comparing medical or physician records to self-reports of endoscopy use showed reasonable agreement (79%) regarding the time point of prior endoscopy only for relatively recent examinations whereas the validity of this information decreased if the endoscopy had been performed more than 4 years before. Also, nonresponder bias might be an issue in health surveys that can often not fully be overcome by weighting factors. In our study using claims data, neither nonresponder nor recall bias played a role.

In comparison with other countries, the results of our study suggest that Germany is one of the countries with the highest 10-year prevalence of overall colonoscopy use in persons aged 55 or older. Only in the US, a higher 10-year prevalence of colonoscopy use in persons aged 50–75 was reported (55–62%) but this information was based on survey data (Chen *et al.*, 2017; Cardoso *et al.*, 2019). Within Europe, an analysis based on data from the European Health Interview Survey suggested that the 10-year prevalence of colonoscopy use in persons aged 50–74 years is highest in Germany, Austria and Luxemburg (~50%), whereas markedly lower prevalences were reported for other countries, for example, for Slovakia (~15%), Finland (~18%) and Norway (~28%) (Cardoso *et al.*, 2020).

Our findings strikingly illustrate that screening colonoscopy provides only a part of the picture of colonoscopy use in Germany, whereas diagnostic colonoscopy plays a major role in most age groups, that is, it is essential to consider both types of colonoscopy when interpreting CRC trends or planning observational studies on CRC screening in Germany. Given that screening colonoscopy is only offered to persons aged 55 or older, the highest levels of (overall) 10-year prevalence were only observed in persons aged 60 or older. According to modelling studies typically proposing a starting age of 50 years or even earlier for CRC screening (Knudsen *et al.*, 2016; Peterse *et al.*, 2018; Chen *et al.*, 2019a), this age pattern seems suboptimal in terms of fully realizing the potential of CRC screening. At the same time, 10-year prevalence of colonoscopy use overall was high even at very high ages, which

raises concerns regarding overdiagnosis. Furthermore, complications due to colonoscopy have been reported to occur more frequently among persons with comorbidities, which are particularly common among older persons (Stock *et al.*, 2013; Chukmaitov *et al.*, 2016; Causada-Calo *et al.*, 2020). With respect to the risk–benefit ratio of colonoscopy use, a shift towards uptake at a younger age of overall and screening colonoscopy would thus be favourable. After decades of opportunistic CRC screening in Germany, an organized screening programme has been introduced in 2019. Since then, letters with information on CRC screening have been sent to all persons aged 50, 55, 60 and 65 and screening colonoscopy has been offered to men already at age 50 (Gemeinsamer Bundesausschuss, 2020). It will be important to monitor whether this change will have a favourable effect on age patterns in colonoscopy use.

In our study, there were no relevant differences in colonoscopy use according to estimates of SES defined by educational level. This is consistent with the results of the analyses by Hermann *et al.* (2015) including 15 014 participants aged 35–60 years of the EPIC study in Germany where no association with educational but a weak positive association with vocational training was observed. In a study by Sieverding *et al.* (2010), also no clear association was found between education and colonoscopy use in Germany in both sexes. This suggests that there is equal access to colonoscopy in Germany, unlike in other countries, where often positive associations between colonoscopy use and level of income or education have been reported (Chen *et al.*, 2017). Furthermore, the absence of relevant differences in colonoscopy use according to regional factors suggests that there are sufficient colonoscopy resources and broad access to colonoscopy across Germany.

In the interpretation of our study, the following limitations should be considered. First, our database (GePaRD) contains all information on colonoscopies performed in the in- and outpatient setting except for diagnostic colonoscopies performed in the hospital but billed as outpatient procedures because patients were not hospitalized. According to estimates of a large health insurance provider in Germany, this kind of billing applied to about 18% of all colonoscopies in 2014 (Friedrich and Tillmanns, 2016). However, according to reasons mentioned in guidelines justifying their conduct, we assume that most of these colonoscopies are early repeat colonoscopies conducted in specific risk constellations (Pox *et al.*, 2013), that is, they are preceded or followed by additional colonoscopies in the outpatient setting and are thus not relevant regarding the prevalence of any colonoscopy. Also, the fact that the prevalence of colonoscopy observed in our study is well in line or even higher than in the report mentioned above from a health insurance provider with access to data on these specific colonoscopies (Tillmanns *et al.*, 2019) supports that they do not

have a relevant impact on prevalence. Unlike previous studies investigating colonoscopy use based on claims data, we were the first to consider an individual estimate of the SES in the analysis. However, it has to be kept in mind that the available information is not optimal: It only takes into account education but no other dimensions such as income, and there was a high proportion of missing values in older age groups (see Supplemental digital content 5, <http://links.lww.com/EJCP/A348>). We only included persons with a continuous insurance period from at least 2006 to 2017. In some countries, such an inclusion criterion would result in systematically excluding unemployed persons who often have a very low SES. In Germany, however, statutory health insurance coverage is independent of occupational status and regulated by the Code of Social Law; so, we do not think that differences by SES have been underestimated due to this inclusion criterion. This is also supported by the fact that our results regarding the association between SES and colonoscopy use were consistent with other studies from Germany as mentioned before. Finally, we cannot rule out that some physicians billed a colonoscopy conducted because of a positive faecal occult blood test as a screening colonoscopy even though coding guidelines state to code it as a diagnostic colonoscopy.

In conclusion, in 2017, about 45–50% of men and women at age 60–84 had a colonoscopy in the previous 10 years of whom about 11–26% had a screening colonoscopy. Analyses stratified by SES and regional factors suggest no relevant social or regional disparities in the utilization of colonoscopy in Germany.

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As we are not the owners of the data, we are not legally entitled to grant access to the data of the German Pharmacoepidemiological Research Database. In accordance with German data protection regulations, access to the data is granted only to BIPS employees on the BIPS premises and in the context of approved research projects. Third parties may only access the data in cooperation with BIPS and after signing an agreement for guest researchers at BIPS.

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Conflicts of interest

There are no conflicts of interest.

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