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Trends in colonoscopy and fecal occult blood test use after the introduction of dual screening offers in Germany: Results from a large population-based study, 2003–2016

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ABSTRACT

An increasing number of countries have recently introduced colorectal cancer (CRC) screening programs. Typically, one specific screening exam, such as fecal occult blood test (FOBT) or flexible sigmoidoscopy, is offered as a primary screening test. We aimed to assess trends in FOBT and colonoscopy use in Germany following the introduction of the offer of screening colonoscopy as an alternative to FOBT in 2002. We used data from 4052 control participants aged 50–79 years recruited during 2003–2016 for a population-based case-control study in Germany. Prevalence of FOBT and colonoscopy lifetime and recent use was analyzed and trends over time were examined. The percentage of all respondents who had ever undergone a colonoscopy (for either screening or diagnostic purpose) increased markedly over time from 44.6% in 2003–2005 to 57.5% in 2013–2016 ($p < 0.0001$). Large increases were also observed for colonoscopy use within 10 years (from 38.0% to 52.8%, $p < 0.0001$), whereas FOBT uptake within one to two years declined from 54.0% to 33.3%. By 2013–2016, 67.2% of respondents either had an FOBT within one to two years or a colonoscopy within 10 years, and this percentage had remained relatively stable over time. This study demonstrates a large increase in colonoscopy utilization since colonoscopy was included as an alternative primary screening test, which was accompanied by a substantial decline in FOBT use. Although the overall adherence to CRC screening recommendations remained stable, the substantial shift of share from FOBT to colonoscopy is expected to yield more protection against CRC incidence and mortality.

1. Introduction

Colorectal cancer (CRC) is a significant cause of cancer morbidity and mortality worldwide. In Germany, > 60,000 people are diagnosed with CRC and > 25,000 people die from the disease every year (Ervik et al., 2016). Screening for CRC, as supported by a large body of evidence, can effectively reduce the disease incidence and mortality (Lin et al., 2016), and is commonly recommended to the average-risk population aged 50 years and older (Bibbins-Domingo et al., 2016; Sung et al., 2015; Arditi et al., 2009).

CRC screening programs are being introduced in a growing number of countries (Schreuders et al., 2015). In many European countries, such as Italy, Spain and The Netherlands, a single screening test, usually fecal occult blood test (guaiac-based FOBT (gFOBT) or increasingly, fecal immunochemical test (FIT)) or sometimes once-only sigmoidoscopy is offered as primary screening test through organized programs that include invitation and reminder system (Salas Trejo et al., 2017; Zorzi et al., 2015; Health Council of the Netherlands, 2009). In very few other countries, e.g. Germany and the US, multiple tests are offered as primary tests and are delivered in an opportunistic way (Bibbins-Domingo et al., 2016; Gemeinsamer Bundesausschuss [Federal Joint Committee], 2009). CRC screening has been offered in Germany since

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1977, when annual gFOBT followed by colonoscopy in case of a positive result was recommended to persons aged 45 years and older. Starting from October 2002, colonoscopy has been included as another primary screening test. People can choose to have two screening colonoscopies with a 10-year interval or biennial FOBTs when they reach 55 years of age, and those aged 50–54 years remain entitled to annual FOBT screening (gFOBT was replaced by FIT in April 2017) (Gemeinsamer Bundesausschuss [Federal Joint Committee], 2009; von der Schulenburg et al., 2010).

It is unclear to what extent such "dual screening offers" are employed by the target populations, which type of screening is more frequently used by specific population groups, and to what extent "dual offers" contribute to achieving high overall adherence rates. The aim of this study was to comprehensively assess trends in gFOBT and colonoscopy use following the implementation of the "dual screening offers" in Germany in 2002. This information will not only enable an evaluation of policy impact on CRC screening test use in Germany, but also provide insights for other countries in the development, implementation and optimization of endoscopic CRC screening programs.

2. Methods

2.1. Study design and study population

This analysis is based on data from the control participants in the DACHS study [Darmkrebs: Chancen der Verhütung durch Screening (colorectal cancer: chances for prevention through screening)], an ongoing population-based case-control study carried out in the Rhine-Neckar region of Germany since 2003. The Rhine-Neckar region is located in the southwest of Germany and has an estimated population of two million residents. Study design and data collection have been described in detail previously (Brenner et al., 2014; Brenner et al., 2011). In brief, patients with a first diagnosis of CRC (C18–20 by International Classification of Diseases Version 10) aged 30 years or older were recruited from the study area. Control participants with no history of CRC were randomly selected from population registers and were frequency matched to cases on age, sex and county of residence. Ethics approval was granted by the ethics committees of the University of Heidelberg and of the Medical Chambers of Baden-Wuerttemberg and Rhineland-Palatinate. Written informed consent was obtained from each study participant.

2.2. Data collection

Selected control participants were contacted by the study center through mail and phone calls and were invited to participate in the study. For people who agreed to participate, personal interviews were then conducted at participants' homes by trained personnel using a standardized questionnaire (available upon reasonable request). Data on socio-demographic characteristics, health-related behaviors and CRC screening test use were collected. Separate questions were asked on the utilization of lower gastrointestinal endoscopy (colonoscopy, sigmoidoscopy or rectoscopy) and FOBT. For both endoscopy and FOBT, respondents were asked whether they ever used the test, and if so, in which calendar year the most recent examination was performed and the total number of examinations they have had. We additionally collected further information on endoscopy use, including the date, the specific test type (colonoscopy, sigmoidoscopy or rectoscopy) and the purpose of the last (up to) three and the very first examinations. For people who refused the home interview, we asked if they were interested in filling out a self-administered short questionnaire, which included key information on demographic characteristics and endoscopy use. If these respondents agreed to participate, they were asked whether they ever used endoscopy and when their last (up to) three and very first endoscopies were performed. Considering that colonoscopy is the predominant lower gastrointestinal endoscopy used in Germany and accounted for > 95% of all endoscopies reported in this study, we uniformly use the term "colonoscopy" to simplify terminology. FOBT use in our study refers to the use of gFOBT, as FIT was included in the German healthcare system as a replacement of gFOBT only in April 2017.

During 2003–2016, a total of 4057 controls aged 50–79 years agreed to participate in the study, through either home interview or self-administered questionnaire, accounting for approximately 55% of all eligible controls aged 50–79 throughout the period of recruitment. Among them, 4052 (99.9%) answered at least the question on ever endoscopy use. Study enrollment was suspended in 2009 due to administrative reasons but continued in 2010 and thereafter.

2.3. Statistical analysis

Descriptive statistics were used to characterize lifetime and recent use of FOBT and colonoscopy by survey year. Survey years were grouped into four generally equal temporal intervals to enable a sufficient sample size for each interval. Being up-to-date with CRC screening was defined as FOBT use within one to two years (i.e. in the current or preceding calendar year) or colonoscopy use (for either screening or diagnostic purpose) within 10 years. Analyses were further stratified by sex and age (50–59, 60–69, 70–79 years). To enable the comparison across subgroups and to make data representative of the German population in the assessed age range in terms of age and sex, percentages were age- and sex-standardized to the 2011 German census population using the direct method (The Federal Health Monitoring System, n.d.). Trends in use over time were tested in logistic regression models with test use as dependent variable and survey year group as independent variable, controlling for changes in the age and sex structure of population over time (respondents' age in five-year category and sex). Wald chi-square statistics were computed and a two-sided < 0.05 p-value was considered statistically significant. A subsidiary analysis was conducted among respondents who were up-to-date with CRC screening to assess the temporal changes in the type of test by which they were up-to-date and to measure overuse of FOBT, defined as FOBT use within 10 years after a prior colonoscopy. Among respondents who reported colonoscopy utilization ever, indications of the most recent colonoscopy were used to calculate the proportion of colonoscopies conducted for screening purposes by survey year. Sensitivity analysis was performed to calculate the proportions among all respondents.

Multivariable logistic regression was performed to investigate the associations between potential determinants and colonoscopy use within 10 years, FOBT use within one to two years and being up-to-date with CRC screening, separately. Potential determinants that were previously discussed in literature were explored in the model: sex (Chen et al., 2017), age (50–59, 60–69, or 70–79 years) (Chen et al., 2017), education (≤ 9, 10–11, or ≥ 12 years) (Chen et al., 2017; Holden et al., 2010), marital status (unmarried/married) (El-Haddad et al., 2015; Stock and Brenner, 2010), residence (village, small city, or large city) (Stock and Brenner, 2010; Fedewa et al., 2015), family history of CRC (yes/no) (Holden et al., 2010), body mass index (BMI; < 25, 25 to < 30, or ≥ 30 kg/m^2) (Maruthur et al., 2012), smoking status (never, former, or current smoker) (Stock and Brenner, 2010; Mahabaleshwarkar et al., 2013), alcohol consumption (women: 0, > 0 to < 20, or ≥ 20 g/day; men: 0, > 0 to < 40, or ≥ 40 g/day) (Mu and Mukamal, 2016), number of health check-ups in the past 5 years (never, 1–4, or ≥ 5 times) (Fedewa et al., 2015; Mahabaleshwarkar et al., 2013; Spaeth and Zwahlen, 2013; Sieverding et al., 2010) and survey year. To examine whether the association between different socio-demographic groups and test use changed over time, an interaction term between survey year and each of the socio-demographic factors was separately added and tested in the logistic regression model that adjusted for all covariates.

Most of our analyses were based on respondents who completed home interviews (3005/4052; 74.2%). Self-administered questionnaire

Table 1
Reported lifetime colonoscopy use among all respondents aged 50–79 years, 2003–2016 (excluding 2009)[a].

	Total	2003–2005 (n = 916)		2006–2008 (n = 940)		2010–2012 (n = 1446)		2013–2016 (n = 750)		Percentage point change, 2003–2016
	N	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	
Overall	4052	449/916	44.6 (39.7–49.5)	532/940	50.5 (44.8–56.3)	901/1446	55.8 (51.5–60.2)	485/750	57.5 (51.6–63.4)	12.9[b]
Sex										
Male	2505	201/430	43.3 (36.1–50.4)	380/663	52.9 (46.1–59.7)	562/919	53.2 (47.9–58.4)	335/493	63.1 (55.6–70.6)	19.8[b]
Female	1547	248/486	45.7 (39.0–52.3)	152/277	48.4 (39.2–57.5)	339/527	58.3 (51.5–65.2)	150/257	52.3 (43.3–61.3)	6.6[b]
Age (year)										
50–59	769	54/158	34.3 (25.1–43.4)	73/177	38.3 (27.8–48.9)	103/260	40.0 (32.2–47.7)	74/174	39.1 (29.7–48.5)	4.8
60–69	1544	212/412	51.4 (44.5–58.4)	180/307	59.0 (50.1–67.9)	355/551	65.8 (58.4–73.1)	179/274	65.0 (54.5–75.5)	13.6[b]
70–79	1739	183/346	52.8 (45.1–60.4)	279/456	59.6 (51.3–67.9)	443/635	70.3 (63.4–77.2)	232/302	75.2 (65.1–85.4)	22.4[b]

Nuse = number of participants with lifetime use of colonoscopy; CI = confidence interval.
[a] Overall percentages are age and sex-standardized to 2011 German census population. Sex-specific estimates are age-standardized and age-specific estimates are sex-standardized to 2011 German census population.
[b] Trends are statistically significant at $\alpha = 0.05$.

respondents (1047/4052; 25.8%) were included in the analysis of overall colonoscopy use. SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used to perform all the analyses and plot the figures.

3. Results

A total of 4052 respondents aged 50–79 years provided basic colonoscopy utilization data (Table 1). Around 60% of them were male and the majority (81.0%) was aged 60–79 years (these proportions reflected matching by sex and age to the CRC cases in the DACHS study). During the study period, the percentage of respondents who reported having ever had colonoscopy increased markedly from 44.6% of 2003–2005 to 57.5% of 2013–2016 ($p < 0.0001$). Statistically significant increases in colonoscopy use were observed for all subgroups except those aged 50–59 years, and larger increases were observed among men and those aged over 60 years than among women and younger adults.

Similar increasing trends in lifetime colonoscopy use were noted among 3005 respondents who completed the home interview (Table 2). The percentage of people reporting colonoscopy use in the past 10 years also increased by 14.8 percentage points during 2003–05 to 2013–16, from 38.0% to 52.8% ($p < 0.0001$). In contrast to the rise in colonoscopy use, the proportion of respondents reporting having ever used FOBT declined by 3.3 percentage points during the study period, and FOBT use within one to two years dropped by 20.7 percentage points, from 54.0% to 33.3% ($p < 0.0001$). Overall, no significant differences over time were evident in the prevalence of being up-to-date with CRC screening, and 67.2% of respondents were up-to-date in 2013–2016. Trends identified for the total population were also observed in sex specific analyses, though the changes were not consistent over time, probably due to the smaller sample size of each sub-category. Generally, larger increases in colonoscopy use were seen among men than among women, and a higher proportion of women reported recent FOBT use than men.

Age-stratified analyses yielded similar increasing trends in colonoscopy use and decreasing trends in FOBT use as identified for the total population (Fig. 1). Changes in being up-to-date with screening were also essentially small. Specifically, larger increases in recent colonoscopy use were observed for age groups over 60 years, while those aged 50–59 years experienced much smaller increases and even slight decreases in the later years. In each survey year group, participants aged 60–69 and 70–79 years were more likely to have used colonoscopy within 10 years and to be up-to-date with screening than younger participants. The percentage of participants who claimed that their most recent colonoscopy was for screening purpose increased substantially during 2003–2016, from 36.6% to 66.0% (Fig. 2). Similar increasing trends in colonoscopy use for screening indication were observed among all respondents, although the absolute proportions were correspondingly lower (Fig. A.1).

Among participants up-to-date with CRC screening, significant differences were evident in the type of test they used (Fig. 3). Most people had used both colonoscopy and FOBT, and around 25.4–33.9% had a colonoscopy followed by an FOBT within 10 years. An increasing percentage of people had used colonoscopy only from 2003 to 2016, whereas the percentage of those reporting only FOBT use declined from 33.3% to 10.8%.

A set of determinants in addition to sex (more frequent FOBT use in women) and age (more frequent colonoscopy use at older ages) were identified to be associated with the use of CRC screening tests (Table 3). Specifically, respondents who had health check-ups in the past 5 years were more likely to have recently used colonoscopy or FOBT. Other factors, such as being married, having CRC family history and alcohol consumption were also associated with increased odds of being up-to-date with screening. In contrast, current smokers were less likely to be up-to-date. The associations between determinants and CRC screening test use did not change significantly over time, except for age ($p < 0.05$ for interaction term) and marital status ($p < 0.05$ for interaction term, for only colonoscopy use within 10 years) (results not shown).

4. Discussion

This analysis of data from a large population-based study provides an insight into the utilization of colonoscopy and gFOBT following the introduction of screening colonoscopy in Germany in 2002. Lifetime use of colonoscopy increased from 44.6% to 57.5% during 2003–2016 among all respondents aged 50–79 years. Large increases were also observed for colonoscopy use within 10 years, whereas gFOBT use within one to two years declined substantially from 54.0% to 33.3% over the same period. Overall, more than two-thirds of respondents were up-to-date with CRC screening as recommended, and this proportion remained relatively stable since the policy change in 2002.

Germany is among the first European countries that implemented a nationwide CRC screening program (Schreuders et al., 2015). Unlike in many other European countries, where a single screening test is used as primary test, two primary tests for people to choose from are offered in Germany. The inclusion of colonoscopy, an invasive but more effective modality into the program as an alternative to FOBT, a long-existing, noninvasive screening test provides a unique opportunity to assess the preference of the general population and whether the offer of colonoscopy screening leads to an increased screening uptake. In our study, following the inclusion of colonoscopy in 2002, there has been a sharp increase in the use of colonoscopy, accompanied by a substantial decline in the use of FOBT, which might reflect the widespread acceptance of colonoscopy by the general German population as a common

Table 2
Reported lifetime and recent colonoscopy and gFOBT use among long questionnaire (home interview) respondents aged 50–79 years, 2003–2016 (excluding 2009)[a].

	2003–2005 (n = 827)		2006–2008 (n = 675)		2010–2012 (n = 1019)		2013–2016 (n = 484)		Percentage point change, 2003–2016
	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	Nuse/N	% (95% CI)	
Total (n = 3005)[b]									
Colonoscopy use									
Ever	418/827	46.2 (41.0–51.4)	403/675	54.3 (47.2–61.3)	660/1019	58.9 (53.5–64.2)	339/484	61.7 (54.2–69.3)	15.5[c]
Within 10 years	337/825	38.0 (33.2–42.7)	360/675	48.9 (42.2–55.7)	604/1017	53.6 (48.5–58.8)	296/483	52.8 (45.9–59.8)	14.8[c]
gFOBT use									
Ever	734/824	87.4 (79.8–95.0)	625/674	90.9 (81.1–100.0)	894/1013	87.1 (80.2–93.9)	413/481	84.1 (74.6–93.5)	−3.3
Within 1–2 years	454/821	54.0 (48.1–59.9)	328/670	47.7 (40.7–54.8)	390/988	40.1 (35.3–45.0)	138/447	33.3 (26.9–39.7)	−20.7[c]
Colonoscopy or gFOBT use									
Up-to-date[d]	577/822	67.4 (60.9–73.9)	495/673	70.5 (62.1–79.0)	759/1009	72.3 (66.1–78.5)	339/472	67.2 (58.8–75.5)	−0.2
Male (n = 1881)[e]									
Colonoscopy use									
Ever	194/406	44.2 (36.9–51.5)	294/488	56.2 (48.2–64.3)	417/662	54.5 (48.2–60.7)	243/325	69.4 (59.7–79.1)	25.2[c]
Within 10 years	159/405	36.9 (30.2–43.7)	262/488	50.2 (42.6–57.9)	382/661	49.4 (43.5–55.3)	216/324	60.6 (51.7–69.5)	23.7[c]
gFOBT use									
Ever	350/405	83.9 (73.6–94.2)	454/487	92.0 (81.3–100.0)	566/657	84.2 (75.7–92.7)	277/323	82.9 (72.0–93.7)	−1.0
Within 1–2 years	203/405	48.2 (40.6–55.9)	241/484	48.7 (41.0–56.4)	247/642	37.7 (31.9–43.5)	85/300	27.6 (21.3–33.8)	−20.6[c]
Colonoscopy or gFOBT use									
Up-to-date[d]	268/405	63.0 (54.2–71.8)	360/487	70.8 (61.6–80.0)	481/654	67.9 (60.5–75.3)	234/319	67.8 (58.3–77.3)	4.8[c]
Female (n = 1124)[f]									
Colonoscopy use									
Ever	224/421	47.9 (40.5–55.2)	109/187	52.5 (41.2–63.8)	243/357	63.1 (54.5–71.7)	96/159	54.5 (43.0–65.9)	6.6[c]
Within 10 years	178/420	38.8 (32.2–45.5)	98/187	47.8 (36.9–58.7)	222/356	57.7 (49.5–66.0)	80/159	45.7 (35.2–56.1)	6.9[c]
gFOBT use									
Ever	384/419	90.7 (79.6–100.0)	171/187	89.8 (73.8–100.0)	328/356	89.6 (79.0–100.0)	136/158	85.3 (70.1–100.0)	−5.4
Within 1–2 years	251/416	59.6 (50.7–68.6)	87/186	47.0 (35.2–58.8)	143/346	42.5 (34.8–50.1)	53/147	39.0 (27.9–50.0)	−20.6[c]
Colonoscopy or gFOBT use									
Up-to-date[d]	309/417	71.5 (61.9–81.2)	135/186	70.5 (56.5–84.6)	278/355	76.6 (66.8–86.4)	105/153	66.9 (53.3–80.5)	−4.6

Nuse = number of participants who used the corresponding tests within defined time frames; CI = confidence interval; gFOBT = guaiac-based fecal occult blood test. When the upper limit of 95% CI exceeds 100%, we keep it as 100%.

[a] Overall percentages are age and sex-standardized to 2011 German census population. Sex-specific estimates are age-standardized to 2011 German census population.

[b] Data missing: colonoscopy use within 10 years: n = 5; gFOBT use ever: n = 13; gFOBT use within 1–2 years: n = 79; up-to-date: n = 29.

[c] Trends are statistically significant at $\alpha = 0.05$.

[d] Up-to-date is defined as colonoscopy use within 10 years or gFOBT use within 1–2 years.

[e] Data missing: colonoscopy use within 10 years: n = 3; gFOBT use ever: n = 9; gFOBT use within 1–2 years: n = 50; up-to-date: n = 16.

[f] Data missing: colonoscopy use within 10 years: n = 2; gFOBT use ever: n = 4; gFOBT use within 1–2 years: n = 29; up-to-date: n = 13.

diagnostic and screening test, their potential preferences for colonoscopy over FOBT for screening and/or increased availability of colonoscopy resources and their use by gastroenterologists. Despite the increased uptake of colonoscopy, the overall prevalence of being up-to-date with screening did not increase significantly over the past 15 years. However, the substantial shift of share from FOBT to colonoscopy would be expected to yield more protection against CRC incidence and mortality, especially in the long run. In fact, there are indications of a substantial and accelerating decrease in CRC incidence and mortality in Germany in recent years (Brenner et al., 2016). The experience from Germany indicates that offering colonoscopy for primary screening helps promote the acceptance and utilization of this invasive test, and this can serve as evidence for other countries in the development of CRC screening strategies that the implementation of endoscopic screening should not be hindered by the fear of potential low uptake.

When compared with previous studies, our estimates of screening test utilization are generally in line with the national survey conducted in 2008–2011, where 54.8% of respondents aged 55–79 years reported colonoscopy use within 10 years (Starker and Sass, 2013). Lower estimates were reported in another health survey performed in Germany over 2004–2005 and an analysis based on claims data of 2000–2008 (Stock and Brenner, 2010; Stock et al., 2011), which might to some degree reflect differences in time windows covered and the inclusion of the very elderly who are less likely to have used screening tests in the two analyses in addition to the different study design in the latter case.

Although overall colonoscopy use has significantly increased, more efforts are needed to further encourage the uptake of screening colonoscopy. According to the annual report of German screening colonoscopy program, around 21–24% of the eligible population had undergone screening colonoscopy within the initial 12 years of the screening offer (Altenhofen et al., 2014). In line with these findings, our study showed that although the proportion of colonoscopies conducted for screening indications increased since the policy change, the translated absolute prevalence of screening colonoscopy use in the general population (as reflected by prevalence of colonoscopy use × proportion of screening colonoscopy) would still be suboptimal, which points to the need to further improve screening colonoscopy adherence.

It is also worth noting that a considerable proportion of people in Germany have used both colonoscopy and FOBT, and quite some people had FOBTs conducted sooner than recommended after a prior colonoscopy. Previous studies have also reported substantial overuse of surveillance colonoscopies in some proportion of participants, along with substantial underuse in other proportions (Stock et al., 2013a; Stock et al., 2013b). The inappropriate use of screening tests might generate

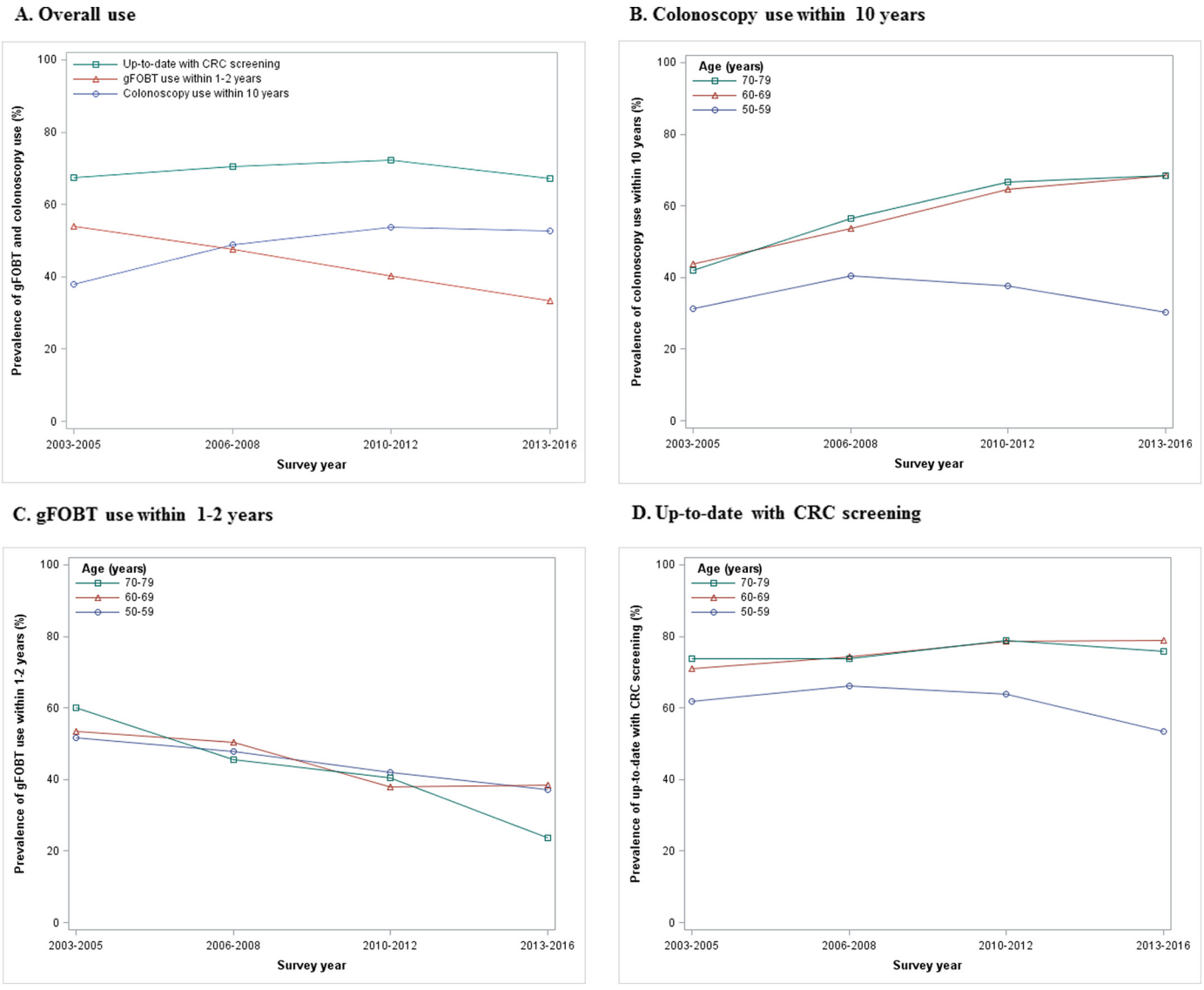

Fig. 1. Colonoscopy and gFOBT use in 2003–2016 (excluding 2009), overall and by age.
CRC = colorectal cancer; gFOBT = guaiac-based fecal occult blood test.
Overall percentages are age and sex-standardized to 2011 German census population. Age-specific estimates are sex-standardized to 2011 German census population.

unnecessary health care expenses and demand for follow-up tests, which should be viewed as an equally important problem as underuse, especially when considering that most of the current efforts are focused on increasing screening uptake (Kruse et al., 2015; Partin et al., 2012).

Disparities in CRC screening test use by age and sex were noted in our study. People aged 60–79 years were more frequently up-to-date with screening than those younger in age, primarily because of their greater use of colonoscopy. In addition, people aged 50–59 years had smaller increases in colonoscopy use than other groups and even slight decreases in the later years. This echoes the national estimates that colonoscopy utilization among men aged 55–59 years only increased marginally from 45% in 2008–2011 to 49% in 2014–2015 and estimate among women decreased from 47% to 43%, while other groups reported much greater increases (Starker and Sass, 2013; Starker et al., 2017). The suboptimal and potentially decreasing utilization calls for more targeted interventions towards this younger age group. Women were more likely than men to have used FOBT and to be up-to-date with CRC screening, which is in line with the findings from a previous German study and is explained to a large extent by gynecologists' active role in patient education and promoting use of screening tests (Stock et al., 2011). No significant difference between men and women was identified in overall colonoscopy use across time, although men had a larger increase. Disparities in endoscopy use by sex in other German studies were also generally small (Stock and Brenner, 2010; Sieverding et al., 2010; Starker and Sass, 2013; Stock et al., 2011; Hermann et al., 2015). Additional factors were identified to be associated with CRC screening test use. Our results of higher utilization of colonoscopy and FOBT among persons with more health check-ups are consistent with available evidence (Fedewa et al., 2015; Mahabaleshwarkar et al., 2013; Spaeth and Zwahlen, 2013; Sieverding et al., 2010), which indicates that people who are more health conscious are more likely to also use cancer screening service. Additionally, in agreement with previous studies from Europe and the US (Stock and Brenner, 2010; Mahabaleshwarkar et al., 2013), current smokers, who are at increased risk of colorectal neoplasms (Hoffmeister et al., 2010; Botteri et al., 2008a; Botteri et al., 2008b) and could potentially benefit more from screening, were even less likely to be up-to-date with CRC screening. Underuse of screening in some specific groups, such as current smokers and those who were obese, was not influenced by the introduction of dual screening offers.

One of the strengths of this study is the continuous collection of CRC screening test use data within one region for almost 15 years, which

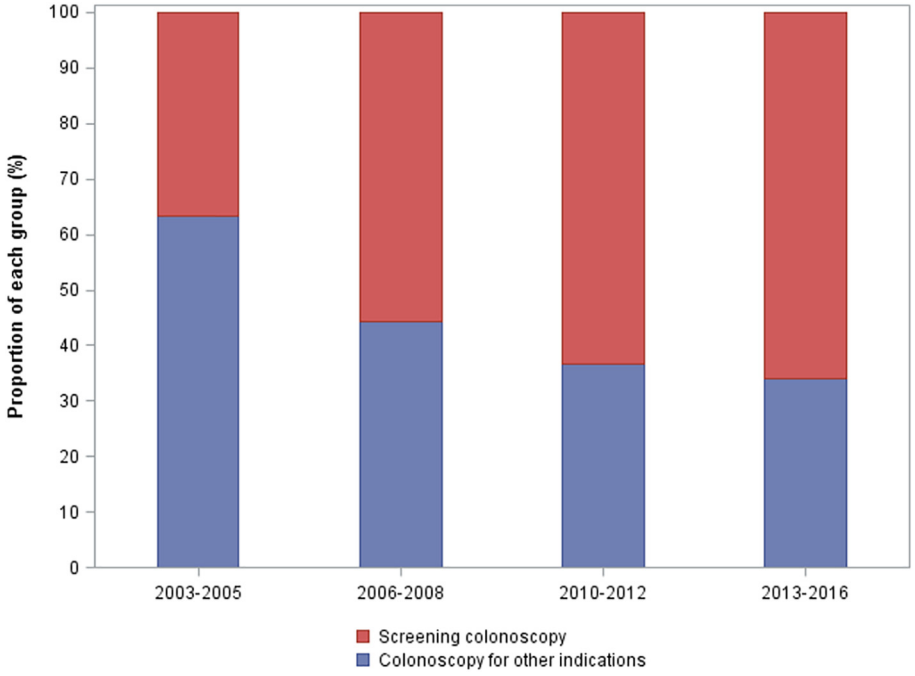

Fig. 2. Proportions of colonoscopies conducted for screening purposes.

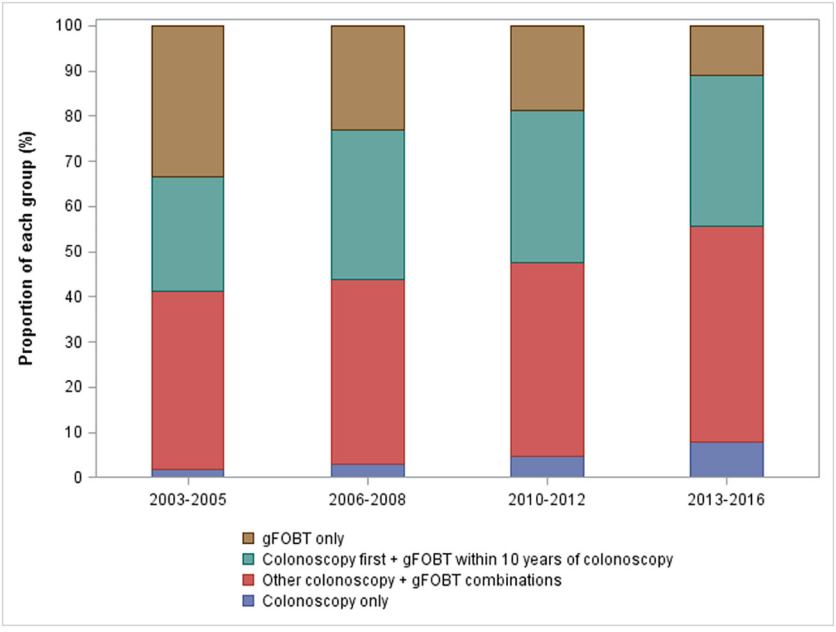

Fig. 3. Proportions of colonoscopy and gFOBT use among participants up-to-date with CRC screening.
CRC = colorectal cancer; gFOBT = guaiac-based fecal occult blood test.

makes it possible to track the utilization over time and analyze the temporal patterns. Some limitations should also be noted when considering the findings of our study. First, as a result of matching of the control participants to the CRC cases, our study population is weighted towards a larger proportion of the elderly and males compared with the general German population aged over 50 years, which however, should not affect the representativeness of our results after age and sex standardization. Second, as around 55% of the eligible controls participated in the study, CRC test use might be overestimated to some extent assuming that more health-conscious people might be more likely to participate in a study like this one. Third, although our data is from one single region, we believe these estimates from the Rhine-Neckar region can essentially reflect the CRC screening test use in Germany. Like all of Germany, Rhine-Neckar region covers both urban and rural areas. Data from the national screening report also showed that FOBT and colonoscopy uptakes in the three federal states where Rhine-Neckar region is located are generally similar to the country average (Altenhofen et al., 2014). Another limitation relates to the relatively small sample size of some sub-categories when performing stratified analyses, which might affect the results of certain sub-groups. Finally, due to the design of the questionnaire, people who used sigmoidoscopy/rectoscopy only cannot be completely differentiated from those who ever used colonoscopy; however, considering that colonoscopy accounted for > 95% of all endoscopies reported in this study and < 2% of people are

Table 3
Odds ratios and 95% confidence intervals from multivariable logistic regression models of colonoscopy and gFOBT use among long questionnaire (home interview) respondents aged 50–79 years.

	Colonoscopy use within 10 years		gFOBT use within 1–2 years		Up-to-date with CRC screening	
	N	OR (95% CI)	N	OR (95% CI)	N	OR (95% CI)
Survey years	2880	1.10 (1.08–1.12)	2815	0.91 (0.89–0.93)	2860	1.02 (1.00–1.05)
Sex						
Male	1810	Reference	1770	Reference	1799	Reference
Female	1070	1.08 (0.91–1.29)	1045	1.25 (1.05–1.50)	1061	1.35 (1.11–1.65)
Age						
50–59	554	Reference	545	Reference	550	Reference
60–69	1123	2.16 (1.73–2.69)	1097	0.90 (0.72–1.12)	1117	1.62 (1.29–2.04)
70–79	1203	2.36 (1.89–2.96)	1173	0.85 (0.68–1.07)	1193	1.78 (1.40–2.27)
Family history of CRC[a]						
No	2559	Reference	2505	Reference	2541	Reference
Yes	321	1.73 (1.35–2.23)	310	0.93 (0.72–1.19)	319	1.42 (1.06–1.90)
Education[b]						
Low	1631	Reference	1603	Reference	1621	Reference
Intermediate	603	1.02 (0.84–1.25)	586	0.97 (0.79–1.19)	599	1.01 (0.81–1.26)
High	646	0.93 (0.76–1.14)	626	0.82 (0.67–1.01)	640	0.90 (0.72–1.13)
Smoking						
Never	1435	Reference	1402	Reference	1424	Reference
Former	1104	1.04 (0.87–1.23)	1080	0.99 (0.84–1.18)	1097	1.09 (0.89–1.32)
Current	341	0.71 (0.55–0.92)	333	0.93 (0.71–1.20)	339	0.76 (0.58–0.99)
Alcohol consumption[c]						
Abstainer	725	Reference	709	Reference	719	Reference
Low	1773	1.34 (1.11–1.62)	1732	1.07 (0.88–1.29)	1762	1.36 (1.11–1.67)
Intermediate-high	382	1.43 (1.09–1.86)	374	1.16 (0.89–1.52)	379	1.50 (1.12–2.03)
BMI						
< 25	907	Reference	888	Reference	903	Reference
25–29.9	1369	1.05 (0.88–1.26)	1339	0.85 (0.71–1.02)	1360	1.01 (0.83–1.24)
≥30	604	0.99 (0.80–1.24)	588	0.71 (0.57–0.89)	597	0.89 (0.70–1.14)
Marital status						
Unmarried	621	Reference	606	Reference	612	Reference
Married	2259	1.34 (1.10–1.62)	2209	1.26 (1.04–1.53)	2248	1.65 (1.35–2.03)
Residence						
Village	1012	Reference	992	Reference	1003	Reference
Small city	1077	1.00 (0.83–1.19)	1055	1.06 (0.88–1.27)	1071	1.05 (0.86–1.29)
Large city	791	0.97 (0.80–1.18)	768	0.75 (0.61–0.92)	786	0.96 (0.77–1.20)
Number of health check-up in the past 5 years						
Never	333	Reference	325	Reference	328	Reference
1–4	1520	1.92 (1.49–2.48)	1484	2.13 (1.62–2.79)	1511	2.47 (1.92–3.18)
≥5	1027	2.32 (1.78–3.04)	1006	3.44 (2.59–4.57)	1021	3.43 (2.61–4.51)

CI = confidence interval; CRC = colorectal cancer; gFOBT = guaiac-based fecal occult blood test; OR = odds ratio.
[a] History of CRC in at least one first-degree relative.
[b] Education: Low: ≤9 year, intermediate: 10–11 year, high: ≥12 years.
[c] Alcohol consumption: Low: Women: > 0 to < 20 g/d, men: > 0 to < 40 g/d; intermediate-high: Women: ≥20 g/d, men: ≥40 g/d.

sigmoidoscopy/rectoscopy-only users based on the strict definition generated from the available endoscopy information, the influence of this would be limited.

5. Conclusions

Our analyses provide up-to-date estimates of FOBT and colonoscopy use in the general population and examine the temporal patterns of utilization in Germany following the introduction of screening colonoscopy. Our study documents a continuously increasing trend for colonoscopy use and decreasing trend for FOBT use following the inception of the screening colonoscopy program in 2002. More than two-thirds of the target population were compliant with screening recommendations, and there is also evidence for some overuse of FOBT after a preceding colonoscopy. Overall prevalence of being up-to-date with screening recommendations remained rather stable, but the shift from use of FOBT to use of colonoscopy is expected to increase the impact on reduction of CRC incidence and mortality. Nevertheless, more efforts are needed to further encourage screening uptake, especially among those underuse groups at particularly high risks, such as smokers, which might be realized by implementing organized screening programs or intervention programs that help remove barriers to the service for those underserved.

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Conflicts of interest

None.

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