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Diabetes and colorectal cancer screening among men and women in the USA: National Health Interview Survey: 2008, 2010

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Abstract
Purpose Adults with diabetes are at increased risk of being diagnosed with and dying from colorectal cancer, but it is unclear whether colorectal cancer screening (CRCS) use is lower in this population. Using the 2008 and 2010 National Health Interview Survey data, we examined whether guideline-concordant CRCS is lower among men and women with self-reported diabetes.
Methods We calculated the weighted percentage of guideline-concordant CRCS and unadjusted and adjusted prevalence ratios (PR) comparing adults aged 51–75 years with diabetes ($n = 6{,}514$) to those without ($n = 8{,}371$). We also examined effect modification by age (51–64 and 65–75), race/ethnicity, and number of medical office visits (0–3, ≥4).
Results The unadjusted prevalence of CRCS among men with diabetes was significantly higher than men without (63.3 vs. 58.0 %; PR = 1.09 95 % CI 1.03–1.16). In adjusted models, this relationship was evident among older [adjusted PR (aPR) = 1.13 95 % CI 1.06–1.21] but not younger men (aPR = 0.99 95 % CI 0.91–1.08; p for interaction term ≤0.01). There was no significant association between diabetes and CRCS among women overall (56.6 vs. 57.9 %; PR = 0.98 95 % CI 0.92–1.04) or by age group. Race/ethnicity and the number of medical visits did not significantly modify the association between diabetes and CRCS for men or women.
Conclusions Men and women with self-reported diabetes were not less likely to be up to date with CRCS than those without diabetes. Older men with diabetes were more likely to be up to date with CRCS than those without diabetes.

Keywords Colorectal cancer · Colorectal cancer screening · Diabetes

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Introduction

Colorectal cancer is the third most commonly diagnosed cancer and cause of cancer death among both men and women in the USA [1]. However, incidence and mortality rates have been decreasing, with much of the recent reduction credited to colorectal cancer screening (CRCS) [2]. Despite the proven effectiveness of CRCS, many adults are not meeting current screening guidelines from the US Preventive Task Force (USPTF) [3]. Current screening guidelines released in 2008 from the USPTF include an annual high-sensitivity home-based fecal occult blood test (HFOBT), a sigmoidoscopy every 5 years with HFOBT every 3 years, or a colonoscopy every 10 years. In 2010, fewer than 60 % of men and women aged 50–75 years had been screened within the recommended time interval, with significant differences by age and race/ethnicity [4]. The percentage of adults aged 50–64 years who met national screening guidelines was 55.0 % compared to 67.9 % of adults aged 65–75 years. By race and ethnicity, the percentage of black (55.0 %) and Hispanic (46.5 %) adults meeting screening guidelines has been found to be significantly lower than white (59.8 %) adults [4].

The risk of colorectal cancer has been found to be 20–40 % higher among adults with diabetes [5–7], and

subsequently, mortality rates are approximately 30 % higher after diagnosis [7, 8]. Adults with diabetes and other chronic conditions utilize the health care system more often than adults without chronic conditions [9, 10]. While the presence of diabetes often necessitates increased interaction with health care providers, allowing for more opportunities of CRCS recommendation by physicians, diabetes management might also compete for the time and focus of physicians as well as the resources of individuals with diabetes, therefore, contending with prevention efforts like CRCS. While some studies have demonstrated lower CRCS use among adults with diabetes [11, 12], other studies have shown either no difference [13, 14] or slightly higher use of screening compared to adults without diabetes [15]. Lower CRCS use among adults with diabetes could possibly contribute to higher mortality rates in this population and indicate a need to target interventions.

In nationally representative studies, results have only been presented for women [12, 14, 15]. Although CRCS rates are similar for men and women overall, uptake of CRCS based on other factors has been found to differ by sex. For instance, men with a usual source of health care, who had seen a general doctor in the past year, or aged ≥65 years were more likely than women in comparable categories to be screened for colorectal cancer [16]. Additionally, previous studies have found differences by sex in the management of diabetes in clinical settings, including decreased receipt of general preventive tests such as lipid screening among women [17–19].

The primary objective of this analysis is to assess whether the prevalence of meeting recommended CRCS guidelines is lower among men and women with diabetes compared to their counterparts without diabetes. Secondarily, we also examined whether the relationships between CRCS and diabetes differed by race/ethnicity, health care utilization, and for those aged above and below 65 years, when most adults become eligible for Medicare and access to health care can change. Our findings may provide insights into whether greater health care utilization among adults with diabetes creates a window of opportunity for screening recommendations or poses challenges that could undermine preventive efforts, such as CRCS. The National Health Interview Survey (NHIS) Cancer Control Supplements provide an opportunity to examine concordance with CRCS guidelines in men and women by diabetes status in a nationally representative sample.

Methods

Data source

We used data from the 2008 and 2010 NHIS and Cancer Control Modules. The NHIS is an in-person household survey conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention since 1957. A more detailed description of the NHIS is available elsewhere [20]. Briefly, the survey uses multistage sampling designed to produce nationally representative estimates of the civilian, non-institutionalized population of the USA. In the sampling design, which includes 2008 and 2010, more than 30,000 households were sampled each year. Socio-demographic information is collected from each household, and one adult is sampled within each household to complete a more in-depth survey. The survey includes questions concerning socio-demographic information, health status, health conditions, disabilities and limitations, behaviors, access to care, and health care utilization. The Cancer Control Modules include questions about cancer screening, diet and nutrition, physical activity, tobacco, genetic testing, family history, and survivorship. The cancer modules have been included with the NHIS in various years since 1987 and are currently given with the survey of the sampled adult within the household [20].

Colorectal Cancer Screening

Within the cancer screening section of the cancer modules, adults aged 40 years and older were asked whether they ever had various types of colorectal examinations or tests and, if yes, when they had it most recently. In both 2008 and 2010, survey participants were asked "Have you ever had a blood stool test, using a home test kit?" The questions about endoscopic exams changed slightly from 2008 to 2010. In 2008, survey participants were asked "Have you ever had a sigmoidoscopy, colonoscopy, or proctoscopy?" In 2010, questions regarding sigmoidoscopy and colonoscopy were asked separately and no longer included proctoscopy but added CT colonography or virtual colonoscopy. Consistent with national measures of CRCS using NHIS data [4, 21], tests were not excluded if respondents answered that their test had been "because of a problem."

Based on the responses to these questions and timing of their most recent screening tests, we dichotomized participants aged 51–75 years (consistent with recommended start and end ages for CRCS in average risk asymptomatic adults [3] and allowing 1 year for getting screened after turning age 50) as guideline concordant or not. In this analysis, participants were considered concordant if they had any endoscopy (sigmoidoscopy, colonoscopy, protoscopy, CT colonography, or virtual colonoscopy) in the past 10 years, or HFOBT in the past year. Any endoscopy in the past 10 years was chosen because it was not possible to determine whether participants had more than one type of endoscopic exam in the 2008 NHIS. Therefore, it is possible for a participant with a sigmoidoscopy 6 years ago as their most recent exam to still be guideline-concordant if

they also had a colonoscopy within 10 years. In addition, there is evidence that self-report of CRCS use may not accurately distinguish between the tests [22, 23].

Diabetes and chronic conditions

Self-reported diabetes and other chronic conditions were based on responses to questions beginning "Have you ever been told by a doctor or other health professional that you had…" Women reporting diabetes occurring only during pregnancy, or adults who responded they had borderline diabetes were considered to not have diabetes. Other chronic conditions included hypertension (if diagnosed on more than one occasion), coronary heart disease, angina pectoris, history of a heart attack or stroke, other heart condition, liver condition, weak or failing kidneys, emphysema, asthma, chronic bronchitis, and previous diagnosis with cancer (excluding non-melanoma skin cancer and colorectal cancer). In the analysis, diabetes was dichotomized into the presence or absence of diabetes; other chronic conditions were aggregated and categorized as 0, 1, or >1 other chronic conditions.

Other covariates

Covariates were considered in this analysis if they had been previously found to be associated with CRCS and/or diabetes. The variables included age group (51–64 years; 65–75 years), race, and ethnicity (Hispanic, non-Hispanic white, non-Hispanic black, Asian, and other non-Hispanic), education level (<high school (HS) degree, HS degree and post-HS coursework/degree), insurance coverage (covered and no coverage), number of medical office visits in the past year (0–3, ≥4), marital status (married/partnered and not married/partnered), and self-reported health status (Excellent/Very Good/Good and Fair/Poor).

Statistical analysis

The analysis was conducted using SAS callable SUDAAN (version 11.0; Research Triangle Institute, Research Triangle Park, NC). All estimates were weighted to account for selection probabilities and non-response. Standard errors were calculated accounting for the complex sample design. The analysis was conducted separately for men and women because of known differences by sex in factors related to CRCS and in the management of diabetes, as described above.

We calculated the weighted percentage of guideline-concordant CRCS by diabetes status and then further stratified by age group, number of medical office visits, and race/ethnicity. To examine the association of guideline-concordant CRCS with diabetes, we first calculated unadjusted prevalence ratios (PR) among those with diabetes versus those without diabetes. Next, we calculated adjusted prevalence ratios (aPR) of CRCS concordance by diabetes status using the PREDMARG statement in SUDAAN's PROC RLOGIST procedure [24]. We used prevalence ratios rather than the more standard odds ratios because guideline-concordant screening is a non-rare outcome. Except for survey year, which was included a priori, covariates were included in a final model if they were significantly predictive of CRCS with a Satterthwaite-adjusted F test ($p < 0.05$) or changed the beta coefficient by ≥10 %. Covariates found to be significantly predictive, or confounders for either men or women were included in all final models for consistency. We examined whether the association between diabetes and CRCS was modified by age group, number of medical office visits, or race/ethnicity in the adjusted models by separately fitting the aforementioned models with an interaction term for each of these variables and diabetes. By race/ethnicity, there were only a sufficient number of Hispanic, white non-Hispanic, and black non-Hispanic participants to produce stratified estimates. Therefore, effect modification by race/ethnicity was conducted in a subset of the study population, limited to these groups.

Study population

There were 16,469 adults aged 51–75 years without a previous diagnosis of colorectal cancer in 2008 ($n = 7{,}291$) and 2010 ($n = 9{,}178$). After excluding adults with missing or insufficient data to determine CRCS concordance or diabetes status, or missing data on covariates ($n = 1{,}584$), there were 14,885 adults (men $n = 6{,}514$; women $n = 8{,}371$) available for analysis. For the subsample analysis of the Hispanic, white non-Hispanic, and black non-Hispanic population, there were 14,050 participants (men $n = 6{,}153$; women $n = 7{,}897$).

Results

An estimated 17.1 % of men reported that they had diabetes (Table 1). The majority of men in the study population were aged 51–64 years (71.1 %) and white non-Hispanic (77.4 %). Over 75 % of men were currently married or partnered. Over 90 % of men were covered by some type of health insurance. Examining the other chronic conditions, 27.7 % of men had more than one and 32.3 % had one. Forty-three percent of men had four or more medical office visits in the past year.

The percentage of women with diabetes was 14.9 % (Table 1). Close to 70 % were aged 51–64 years (69.2 %) and over 75 % were white non-Hispanic (75.5 %).

Table 1 Distribution of socio-demographic, health-related, and access to care characteristics by sex among adults aged 51–75; National Health Interview Survey, 2008, 2010

	Men (n = 6,514)		Women (n = 8,371)	
	n	Weighted %	n	Weighted %
No diabetes	5,323	83.0	6,978	85.2
Diabetes	1,191	17.0	1,393	14.9
Survey year				
2008	2,932	49.8	3,755	49.5
2010	3,582	50.2	4,616	50.5
Age				
51–64	4,396	71.1	5,529	69.1
65–76	2,118	28.9	2,842	30.9
Race/ethnicity				
Hispanic	729	8.6	1,070	8.5
White non-Hispanic	4,436	77.5	5,480	75.7
Black non-Hispanic	988	9.5	1,347	10.9
Asian	312	3.7	395	3.9
All other races	49	0.7	79	1.0
Education				
<High school (HS)	1,114	14.6	1,429	14.3
HS graduate	1,745	26.3	2,498	30.5
>HS	3,655	59.1	4,444	55.2
Marital status				
Married/partnered	4,065	75.7	4,365	36.6
Not married/partnered	2,449	24.3	4,006	63.4
Insurance status				
Covered	5,825	90.7	7,538	90.9
No coverage	689	9.3	833	9.1
Self-reported health				
Excellent/very good/good	5,158	81.6	6,567	81.3
Fair/poor	1,356	18.4	1,804	18.7
Other chronic conditions				
0 Conditions	2,534	39.7	3,082	38.4
1 Condition	2,092	32.4	2,928	34.8
>1 Conditions	1,888	27.9	2,361	26.8
Medical office visits past year				
0–3 Visits	3,696	56.8	4,023	48.3
≥4 Visits	2,818	43.2	4,348	51.7

Approximately 63 % were currently married or partnered and over 90 % had health insurance coverage. Almost 35 % of women had one other chronic condition (34.9 %) and 26.6 % had more than one. Just over half (51.5 %) of women had four or more medical office visits in the past year.

Among men, CRCS was higher among adults with diabetes (63.3 %) compared to those without it (58.0 %; PR = 1.09 95 % CI 1.03–1.16) (Table 2). When stratified by age group, the significant difference was only found among men aged 65–75 years. In this older age group, the prevalence of guideline-concordant screening was 75.5 % among men with diabetes compared to 66.4 % among men without it (PR = 1.14 95 % CI 1.06–1.22). After adjusting for age, race/ethnicity, marital status, educational level, self-reported health status, other chronic conditions, health insurance coverage, and survey year, the overall association among men was attenuated and the association between CRCS and diabetes was no longer statistically significant (aPR = 1.05 95 % CI 0.99–1.11) (Table 2). However, by age group, the association between CRCS and diabetes among men aged 65–75 years remained after adjusting for other factors (aPR = 1.13 95 % CI 1.06–1.21). There was no significant association with CRCS among men aged 51–64 years. The p value for the interaction term between diabetes and age group was statistically significant (p = 0.005).

When stratified by the number of medical office visits in the past year, there was no significant difference in meeting screening guidelines by diabetes status among men (Table 2). In multivariable models, the p value for interaction between diabetes and medical office visits was not statistically significant (p = 0.09). However, men with or without diabetes and 0–3 medical office visits (54.1 and 49.2 %, respectively) had a significantly lower prevalence of meeting CRCS guidelines compared to those with ≥4 visits (68.1 and 72.1 %, respectively).

The prevalence of guideline-concordant CRCS was close to 20 percentage points lower for Hispanic men with and without diabetes compared to respective categories among white non-Hispanic men (Table 3). Effect modification of the association between diabetes status and CRCS by race/ethnicity was not statistically significant (p = 0.08), indicating that the associations did not significantly differ across the groups. That is, the elevated association found among black non-Hispanic men (aPR = 1.23 95 % CI 1.08–1.40) was not significantly different than the observed associations among Hispanic (aPR = 0.97 95 % CI 0.78–1.21) and white non-Hispanic men (aPR = 1.03 95 % CI 0.95–1.11).

Among women, there was no significant difference in CRCS for those with diabetes compared to those without (56.6 and 57.9 %, respectively; PR = 0.98 95 % CI 0.92–1.04), and there was no difference in either age group (Table 2). There was also no association between diabetes and CRCS in the adjusted models. Furthermore, the p value for the interaction term between diabetes and age group was not statistically significant (p = 0.95), indicating that the null association between diabetes and CRCS among women was not modified by age group.

The percent of women meeting CRCS guidelines was significantly higher among women with or without diabetes and ≥4 medical office visits (61.5 and 67.2 %, respectively) compared to comparable women with 0–3 visits (43.1 and 49.2 %, respectively). Women with diabetes and ≥4 medical visits had a significantly lower prevalence of guideline-concordant CRCS compared to women without

Table 2 Prevalence and prevalence ratios (PR) with corresponding 95 % confidence intervals (CI) for guideline-concordant colorectal cancer screening by diabetes status, sex, and medical visits; adults aged 51–75 years, National Health Interview Survey, 2008, 2010

	Weighted % (95 % CI)	Unadjusted PR (95 % CI)	Adjusted PR[a] (95 % CI)	*p* value for interaction[b]
Men (n = 6,514)				
Diabetes	63.3 (60.0–66.7)	1.09 (1.03–1.16)	1.05 (0.99–1.11)	[c]
No diabetes	58.0 (56.3–59.7)	1.0 (Ref)	1.0 (Ref)	
Age group				
51–64 years				
Diabetes	56.2 (51.7–60.7)	1.03 (0.9–1.12)	0.99 (0.91–1.08)	0.005
No diabetes	54.8 (52.9–56.8)	1.0 (Ref)	1.0 (Ref)	
65–75 years				
Diabetes	75.5 (71.2–79.7)	1.14 (1.06–1.22)	1.13 (1.06–1.21)	
No diabetes	66.4 (63.5–69.3)	1.0 (Ref)	1.0 (Ref)	
Medical visits past year				
0–3 Visits				
Diabetes	54.1 (47.9–60.3)	1.10 (0.98–1.24)	1.08 (0.97–1.22)	0.09
No diabetes	49.2 (47.0–51.3)	1.0 (Ref)	1.0 (Ref)	
≥4 Visits				
Diabetes	68.1 (63.9–72.3)	0.94 (0.88–1.01)	0.96 (0.90–1.03)	
No diabetes	72.1 (69.9–74.3)	1.0 (Ref)	1.0 (Ref)	
Women (n = 8,371)				
Diabetes	56.6 (53.3–59.8)	0.98 (0.92–1.04)	0.98 (0.92–1.04)	[c]
No diabetes	57.9 (56.4–59.4)	1.0 (Ref)	1.0 (Ref)	
Age group				
51–64 years				
Diabetes	53.3 (49.1–57.5)	0.97 (0.89–1.05)	0.98 (0.90–1.07)	0.95
No diabetes	55.1 (53.3–56.9)	1.0 (Ref)	1.0 (Ref)	
65–75 years				
Diabetes	61.6 (56.5–66.6)	0.96 (0.88–1.04)	0.98 (0.90–1.07)	
No diabetes	64.4 (62.1–66.7)	1.0 (Ref)	1.0 (Ref)	
Medical visits past year				
0–3 Visits				
Diabetes	43.1 (36.4–49.8)	0.88 (0.75–1.02)	0.89 (0.76–1.03)	0.46
No diabetes	49.2 (47.3–51.2)	1.0 (Ref)	1.0 (Ref)	
≥4 Visits				
Diabetes	61.5 (57.8–65.3)	0.92 (0.85–0.98)	0.96 (0.90–1.03)	
No diabetes	67.2 (64.9–69.5)	1.0 (Ref)	1.0 (Ref)	

Any endoscopy (sigmoidoscopy, colonoscopy, protoscopy, CT colonography or virtual colonoscopy) in the past 10 years, or a home-based fecal occult blood test (HFOBT) in the past year)

[a] Overall results adjusted for age, race and ethnicity, marital status, educational level, self-reported health status, other chronic conditions, health insurance coverage, and survey year. Results stratified by age and medical visits also include an interaction term for diabetes/age or diabetes/medical visits

[b] *p* values based on Satterthwaite-adjusted *F* test from adjusted models

[c] Does not apply

diabetes (PR = 0.92 95 % CI 0.85–0.98). However, the association was attenuated and no longer statistically significant after adjusting for other factors (aPR = 0.96 95 % CI 0.90–1.04).

Hispanic women without diabetes had the lowest prevalence of guideline-concordant CRCS compared to the other race/ethnicities (Table 3). There was no significant difference in CRCS by diabetes status among Hispanic, white and black non-Hispanic women in unadjusted and multivariable analyses. The *p* value for the interaction term of race/ethnicity with diabetes was not statistically significant ($p = 0.25$).

Discussion

Although adults with diabetes are at increased risk of being diagnosed with colorectal cancer [5–7], it is unclear from earlier studies if they are less likely to undergo CRCS, which could contribute to higher mortality rates. In addition, previous studies have not provided results for men and women separately. Using data from the 2008 and 2010 NHIS, we found that neither women aged 51–75 years nor men aged 51–64 years with diabetes were less likely to be screened for colorectal cancer compared to their counterparts without diabetes. Guideline-concordant CRCS was

Table 3 Prevalence and prevalence ratios (PR) with corresponding 95 % confidence intervals (CI) for guideline-concordant colorectal cancer screening by diabetes status, sex, and race/ethnicity; adults aged 51–75 years, National Health Interview Survey, 2008, 2010

	Weighted % (95 % CI)	Unadjusted PR (95 % CI)	Adjusted PR[a] (95 % CI)	*p* value for interaction[b]
Men (n = 6,153)				
Race/ethnicity				
Hispanic				
Diabetes	45.3 (36.4–54.5)	1.13 (0.89–1.44)	0.97 (0.78–1.21)	0.08
No diabetes	40.1 (35.3–45.1)	1.0 (Ref)	1.0 (Ref)	
White non-Hispanic				
Diabetes	66.6 (62.3–70.7)	1.09 (1.01–1.17)	1.03 (0.95–1.11)	
No diabetes	61.2 (59.3–63.0)	1.0 (Ref)	1.0 (Ref)	
Black non-Hispanic				
Diabetes	65.7 (58.5–72.2)	1.37 (1.19–1.57)	1.23 (1.08–1.40)	
No diabetes	48.0 (43.6–52.4)	1.0 (Ref)	1.0 (Ref)	
Women (n = 7,897)				
Race/ethnicity				
Hispanic				
Diabetes	48.5 (41.8–55.2)	1.08 (0.92–1.28)	1.03 (0.90–1.19)	0.25
No diabetes	44.7 (40.5–49.0)	1.0 (Ref)	1.0 (Ref)	
White non-Hispanic				
Diabetes	58.5 (54.2–62.7)	0.97 (0.90–1.05)	0.96 (0.88–1.04)	
No diabetes	60.0 (58.3–61.7)	1.0 (Ref)	1.0 (Ref)	
Black non-Hispanic				
Diabetes	61.1 (53.7–68.1)	1.09 (0.95–1.26)	1.07 (0.94–1.23)	
No diabetes	55.9 (51.8–60.0)	1.0 (Ref)	1.0 (Ref)	

Any endoscopy (sigmoidoscopy, colonoscopy, protoscopy, CT colonography, or virtual colonoscopy) in the past 10 years, or a home-based fecal occult blood test (HFOBT) in the past year)

[a] Results are adjusted for age, marital status, educational level, self-reported health status, other chronic conditions, health insurance coverage, and survey year and include an interaction term for diabetes and race/ethnicity. Results exclude Asian participants and those of all other race/ethnicities because there were insufficient numbers

[b] *p* values based on Satterthwaite-adjusted *F* test from adjusted models

higher among men aged 65–75 years with diabetes compared to those without diabetes.

Of the three previous national studies, our finding of no relationship between CRCS and diabetes among women is consistent with the prior analysis of NHIS data from 2005 [14]. The other two studies found both higher [15] and lower [12] use of CRCS among women with diabetes compared to those without. Our finding may differ from these two studies due to differences in sources used to identify CRCS tests (e.g., self-report vs. medical claims) and time period examined or to due differences in survey methods or questions.

The relationship between CRCS and diabetes among men has not been previously reported at the national level. Of the previous studies that did include men, results were not presented by age group [11, 13]. It remains unclear why CRCS differs by diabetes status among older men, but not among younger men. It is possible that changes in access to care or health care utilization due to Medicare eligibility at age 65 contribute to this result.

A number of sex-specific behaviors, perceptions, and barriers related to CRCS could possibly contribute to differences in uptake of CRCS between men and women. Brawarsky et al. [25] found that although men had not been more likely than women to be recommended CRCS, they had been more likely to adhere to the recommendation and to be tested. In addition, previous studies found examples of differences in how men and women perceived the risk of colorectal cancer, as well as the preparation and test expense as barriers to screening [26, 27]. It is not clear whether and how these factors change with age among men and women.

Among men, effect modification of the relationship between CRCS and diabetes was not statistically significant by race/ethnicity; however, the aPR was elevated among black non-Hispanic men but not among Hispanic

nor white non-Hispanic men. Very few studies have examined CRCS behavior separately by race/ethnicity and gender. In a study of a predominantly male (96 %) Veterans Administration population, Burgess et al. [28] did find significant differences in CRCS adherence among black and white veterans by levels of income, education, and marital status.

The prevalence of guideline-concordant CRCS was higher among both men and women with ≥4 medical office visits, regardless of diabetes status. However, the association between diabetes and CRCS was not modified by the number of visits. This result suggests that an increased number of medical visits may be more likely to facilitate CRCS rather than acts as a barrier. These findings are consistent with prior research in both urban and rural populations demonstrating that patients with diabetes and a greater number of physician visits were more likely to have been screened for colorectal cancer than those with fewer visits [11, 29]. Patients with chronic conditions and multiple morbidities have been found to have greater contact with the health care system [9], which in turn has been found to be associated with an increased likelihood of being screened [29, 30]. However, Schenck et al. [30] found that the number of medical visits alone had not been sufficient to predict CRCS and that the type of visit and provider had been important factors as well.

One limitation of this analysis is the reliance on self-reported data, particularly for CRCS. Previous research has suggested that estimates may be inflated and systematic differences by race/ethnicity and gender may be introduced with use of self-reported data [31]. Additionally, the colorectal tests could have been performed for diagnostic instead of screening purposes. However, when we conducted a sensitivity analysis excluding those who reported having any of the tests because of a problem, results did not meaningfully change. Another limitation is the inability to assess the presence of certain morbidities (e.g., inflammatory bowel disease and Crohn's disease) or severity, which can increase or decrease the likelihood of health care provider recommendation for CRCS, as well as produce competing demands during medical visits.

Overall, we did not find that men and women with diabetes had been less likely to be up to date with CRCS than those without diabetes, but we did find subgroups of men in which those with diabetes were more likely to be up to date with CRCS than those without. Regardless of diabetes status, the prevalence of guideline-concordant CRCS was higher with greater health care utilization. Still, fewer than 60 % of men and women aged 51–64 years, with or without diabetes, are up to date with CRCS and only men aged 65–75 years with diabetes reached the Healthy People target of 70.5 % for CRCS [32].

Conflict of interest The authors declare that they have no conflict of interest.

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