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The Effects Of The Affordable Care Act On The Receipt Of Colonoscopies Among Insured Elderly

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THE EFFECTS OF THE AFFORDABLE CARE ACT ON THE RECEIPT OF COLONOSCOPIES AMONG INSURED ELDERLY

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DEDICATION

This work is dedicated to God and to my father and my mother. Without their support, love, and encouragement, it would not have been possible. Their belief in my ability and encouragement to be the best has spurred me on to greater heights.

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ABSTRACT

Background: The Affordable Care Act (ACA) waived deductibles and eliminated coinsurance for colonoscopies for Medicare beneficiaries beginning on January 1, 2011. This study investigated the effect of the ACA's removing of financial barriers on the receipt of colonoscopies among insured elderly, who are predominantly covered by Medicare. Moreover, this study examined how income-related disparities in colonoscopy use have changed over the past decade and attempted to quantify various contributions to income-related disparity in the use of colonoscopies among insured elderly.

Methods: Five cycles (2008, 2010, 2012, 2014, and 2016) of the Behavioral Risk Factor Surveillance System (BRFSS) were utilized to examine the receipt of colonoscopies among insured elderly aged 65 to 75 prior to the implementation of ACA and then again afterwards. To examine income-related disparities in the use of colonoscopies, individuals aged 65 to 75 were included, and the Concentration Index (CI) was calculated before and after implementation of the ACA. To identify and quantify the contribution of each factor, decomposition of the CIs was conducted.

Results: Of 349,899 eligible elderly insured in the age group 65 to 75 years, 236,275 (68%) had received a colonoscopy in the previous 10 years. The receipt of colonoscopies increased from 63% in the pre-ACA years to 70% in the post-ACA years ($p<.001$). Compared with the pre-ACA period, colonoscopy uptake during post-ACA years shows an odds ratio of 1.15 (95% confidence limit [CI] = 1.08-1.22, $p<.001$) after adjusting for

time dependent improvements in colonoscopies and other relevant factors. CIs indicated that disparities in colonoscopy use were lessened after the implementation of the ACA. Decomposition analyses showed that whereas decreases in disparities derived largely from income and educational levels, higher levels of income and educational attainment continue to be major contributors to the observed disparities in colonoscopy use. Conclusions: Following the implementation of the ACA, a statistically significant increases in colonoscopy use was observed and may contribute to the observed decreases in the disparity of colonoscopy use. This suggests that eliminating financial barriers to access has improved the CRC screening rate, but achieving the national goal of 80% coverage and the Healthy People 2020 goal will require additional interventions to encourage higher screening levels.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACA .....Affordable Care Act

ACN .....Advanced Colorectal Neoplasia

AMA .....American Medical Association

AWV ..... Annual Wellness Visit

BRFSS.....Behavioral Risk Factor Surveillance System

CDC .....Centers for Disease Control and Prevention

CMS ..... Centers for Medicare and Medicaid Services

CRC.....Colorectal Cancer

FDA.....United States Food and Drug Administration

HHS..... United States Department of Health and Human Services

HP2020 .....Healthy People 2020

MEI ..... Marginal Efficiency of Investment

MIPPA .....Medicare Improvement for Patients and Providers Act

NCCRT ..... National Colorectal Cancer Roundtable

NCQA .....National Committee for Quality Assurance

RCT..... Randomized Controlled Trial

USPSTF .....United States Preventive Services Task Force

WMV ..... Welcome to Medicare Visit

CHAPTER 1

INTRODUCTION

Colorectal cancer (CRC) is the second leading cause of cancer deaths for both men and women in the United States (Siegel, Miller et al. 2017). There were an estimated 135,430 new cases and 50,260 deaths from CRC in 2017 (Siegel, Miller et al. 2017). Early detection of CRC through routine screening has been demonstrated to be effective in reducing the incidence of and mortality from this disease (Edwards, Ward et al. 2010, Lin, Piper et al. 2016, Siegel, Miller et al. 2017). The U.S. Preventive Services Task Force (USPSTF) strongly recommends screening for CRC beginning at the age of 50 and continuing until the age of 75 for individuals at average risk, implying that increases in screening for CRC result in decreases for CRC mortality (Koretz 2016, Lin, Piper et al. 2016, US Preventive Services Task Force 2016).

USPSTF has recommended a number of different screening tests for use in detecting early-stage CRC and preventing incident cases, including 1) flexible sigmoidoscopy every 5 years, 2) FIT-DNA every 1 or 3 years, 3) fecal occult blood test or fecal immunochemical testing every year, 4) CT colonography every 5 years, 5) flexible sigmoidoscopy every 10 years plus FIT every year, and (6) colonoscopy every 10 years (US Preventive Services Task Force 2016). The USPSTF recommends screening using any of the accepted methods, as any type of screening test would be better than no screening at all (Atkin, Edwards et al. 2010, Quintero, Castells et al. 2012, Patel and

Kilgore 2015, US Preventive Services Task Force 2016). All the screening options are not equally attractive to all individuals; depending upon health history and preferences of individuals, the choices may differ significantly. However, from a clinical perspective, colonoscopy is the preferred method, because a colonoscopy allows doctors to examine the entire length of the colon and remove all cancers and precancerous polyps during a single procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016). Colonoscopy is also recommended as a follow-up when another CRC screening is positive. Moreover, colonoscopy has been validated in a randomized trial to have a mortality reduction benefit (Zauber, Winawer et al. 2012, Patel and Kilgore 2015, Koretz 2016, US Preventive Services Task Force 2016).

The mortality rate from CRC has decreased steadily since 1980 (Weir, Thompson et al. 2015, Siegel, Miller et al. 2017), which may be attributable partially to removal of pre-cancerous, adenomatous polyps at an early stage based on diagnosis of CRC and partially to widespread use of colonoscopies or other screening approaches (Cunningham, Atkin et al. 2010, Edwards, Ward et al. 2010, Lieberman 2010, Martin, Tully et al. 2017, Partin, Gravely et al. 2017). Nonetheless, self-reported CRC screening rates in the National Health Interview Survey are at 62%, and the National Committee for Quality Assurance (NCQA) indicates that 60% of commercial insurance members and 69% of Medicare plan members received an appropriate CRC screening in 2016 (Paskett and Khuri 2015, White, Thompson et al. 2017). Moreover, Behavioral Risk Factor Surveillance System (BRFSS) data indicate that around 65% of adults aged 50 to 75 reported having had one of the colorectal screening tests recommended by USPSTF, and

around 60% of adults aged 50 to 75 had received a colonoscopy within the last 10 years (Joseph, King et al. 2012, Liss and Baker 2014).

The US Department of Health and Human Services (HHS) initiated Healthy People 2020 (HP2020), which covered several objectives for reducing cancer mortality. Each objective was assigned a baseline measure in 2007 and a target to be achieved by 2020. HP2020 calls for a 15% reduction in death rates from 2007 to 2020 for CRC (Weir, Thompson et al. 2015). Moreover, the National Colorectal Cancer Roundtable (NCCRT) initiated a goal to increase the CRC screening rate to 80% in the eligible population by 2018 (Karlitz, Oliphant et al. 2017). Achieving this goal would avert 280,000 new cases of CRC and 200,000 deaths from the disease by 2030, and 24.4 million people would be screened (Fedewa, Ma et al. 2015, Meester, Doubeni et al. 2015). Nonetheless, the aforementioned screening rates are lower than the use of preventive interventions for other screening-amenable cancers, below the 80% coverage of the CRC screening target, and below the HP2020 target of 71% (Swan, Breen et al. 2010, Karlitz, Oliphant et al. 2017, White, Thompson et al. 2017).

One potential barrier to CRC screening is the associated out-of-pocket financial costs (Howard, Guy et al. 2014). The financial costs may significantly dampen patients' willingness to adopt any preventive procedures, including any of the recommended CRC screenings. This is especially true for colonoscopies, which usually involved relatively high cost-sharing requirements prior to the ACA policy change in 2011 (Klabunde, Riley et al. 2004, Hamman and Kapinos 2015). Previous studies have shown that cost-sharing reduces preventive health care use, including the use of highly effective screening tests (Busch, Barry et al. 2006, Goodwin and Anderson 2012). One study found that waiving

coinsurance for colonoscopies resulted in an 18% increase in screenings (Khatami, Xuan et al. 2012).

To address the negative consequences of financial barriers on the use of preventive services and to promote CRC screening, the Affordable Care Act (ACA) requires all non-grandfathered private health plans to offer coverage of CRC screening without cost-sharing. Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, although not for diagnostic ones (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Therefore, Medicare beneficiaries may face unexpected out-of-pocket liabilities when a polyp is detected and removed during a colonoscopy, in which case the patients are billed a copay. Medicare beneficiaries are also responsible for Part B deductibles and coinsurance when a colonoscopy is performed as part of a two-step screening process after another CRC screening is positive (Howard, Guy et al. 2014). Nevertheless, the ACA policy change, in general, implies that the elderly insured population should see significant reductions in out-of-pocket expenses associated with colonoscopies.

Research on the effects of cost-sharing reductions to utilization of preventive health care has received significant attention from researchers and policy makers; but surprisingly, only a few studies have assessed the effect of cost-sharing reduction on colonoscopies among the elderly insured population, including the Medicare beneficiaries, following the implementation of the ACA (Hamman and Kapinos 2015, Cooper, Kou et al. 2016). The few studies that have examined this issue used a very short time-frame beginning with the implementation of the ACA, so they may have

underestimated the effects of the ACA cost-sharing reduction. Furthermore, these studies yielded variable results concerning the receipt of colonoscopies following the changes in coverage post-ACA (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Cooper, Kou et al. 2016); and they have not been able to determine whether eliminating financial barriers might have helped socioeconomically vulnerable Medicare beneficiaries more than other groups. Moreover, these studies have not examined the ACA's impact on screening disparities among the elderly insured. It is true that some of the socioeconomically vulnerable elderly may be enrolled in Medicaid; and in that case, these individuals would have received colonoscopies with no out-of-pocket expenses in the pre-ACA years. However, this should not affect the results significantly as almost all elderly are enrolled in Medicare and only a relatively small percentage are enrolled in Medicaid (Medicaid only or dually eligible) (Grabowski, 2012).

Thus, to address these gaps in current research, this study aimed to examine the changes in colonoscopy use among the elderly insured population, including Medicare beneficiaries, following the implementation of the ACA policy for preventive services. Our hypothesis was that the elderly insured population have a greater likelihood of undergoing colonoscopies following the implementation of the ACA. We also wanted to determine whether the ACA policy changes have helped the socioeconomically vulnerable elderly more than others.

This study consists of two manuscripts. The first manuscript of the dissertation examined the effect of the ACA cost-sharing reduction on the receipt of colonoscopy among the elderly insured population. This study aimed to examine how the ACA cost-sharing reduction has changed colonoscopy use among the elderly insured and to assess

the various factors that affect the receipt of colonoscopies. The second manuscript examined how disparities in colonoscopy use in the United States have changed over the past decade, in line with the implementation of the ACA and attempted to quantify the contributions to the disparity in the use of colonoscopies among elderly insured.

The dissertation is organized into five chapters, including two manuscripts. Chapter 1 provides the background information and the rationale of the study. Chapter 2 describes a review of the scientific literature that provides a current understanding of colorectal cancer screening and of efforts to improve colorectal cancer screening. Knowledge gaps are also stated. Chapter 3 presents the methodology of the study. Chapter 4 presents the two manuscripts. Chapter 5 includes the overall discussion, conclusions, and implications for future research.

CHAPTER 2

BACKGROUND AND SIGNIFICANCE

2.1 Colorectal Cancer

Colorectal cancer (CRC) is a type of cancer that develops in the colon or rectum, and over two thirds of CRCs in the United States are found in the colon (Murphy, Harlan et al. 2015). Most forms of CRC grow slowly over a decade or more. CRC symptoms depend on the location and size of the cancer. Prior studies have shown that symptoms, such as changes in bowel habits, changes in stool consistency, blood in the stool, rectal bleeding, abdominal discomfort, and unintended weight loss, are associated with CRC; but they are also common in individuals without cancer, which indicates poor sensitivity in self-diagnosis of CRC (Jellema, van der Windt et al. 2010, Astin, Griffin et al. 2011, Williams, Cubiella et al. 2016). Symptoms alone cannot be the determinant of CRC; therefore, identifying patients who should be referred for diagnostic colonoscopy remains a challenge (Williams, Cubiella et al. 2016).

There were an estimated 135,430 new cases of and 50,260 deaths from CRC in 2017 (Siegel, Miller et al. 2017). Although the majority of new cases develop in people aged 65 or older, 45% of men and 39% of women are younger than age 65 years old at diagnosis (Siegel, Miller et al. 2017). Among men, 18% of cases and 27% of deaths

develop in those aged 80 or older, compared with 27% of cases and 40% of deaths, respectively, among women (Siegel, Miller et al. 2017). The mean age at death from CRC is 73 years (US Preventive Services Task Force 2016). Incidence and mortality rates have been decreasing for several decades as a consequence of historical changes in risk factors, the introduction and dissemination of screening tests, and advancements in treatment (Edwards, Ward et al. 2010, Lin, Piper et al. 2016, Martin, Tully et al. 2017).

CRC is the third most commonly diagnosed malignancy and the second leading cause of cancer deaths for both men and women in the United States (Siegel, Miller et al. 2017). From 2009-2013, the annual age-standardized incidence rate for CRC in the United States was 41 per 100,000 persons, and from 2010-2014 the mortality rate was 15 per 100,000 persons (Siegel, Miller et al. 2017). Despite the fact that the lifetime risk of disease is no different in men (5%) than in women (4%), the incidence rate was 30% higher in men, and the mortality rate was 40% higher in men (Siegel, Miller et al. 2017). Sex disparities also vary by age. For example, the incidence rate was 132 per 100,000 men aged 55 to 74 years and 91 per 100,000 women aged 55 to 74 years (Siegel, Miller et al. 2017). The higher rates in men can be explained by differences in exposures to risk factors and sex hormones, as well as complex interactions between these forces (Murphy, Devesa et al. 2011).

CRC incidence and mortality rates differ considerably by race and ethnicity (Siegel, Miller et al. 2017). Among the five major racial and ethnic subgroups (Non-Hispanic white, Non-Hispanic black, Asian Americans and Pacific Islanders, Native Americans and Native Alaskans, and Hispanic), rates were highest in non-Hispanic blacks and lowest in Asian Americans and Pacific Islanders. Non-Hispanic blacks have

the highest incidence of and mortality rates from CRC and almost double the CRC mortality rate of other racial and ethnic minorities (Williams, Cubiella et al. 2016). From 2009 through 2013, CRC incidence rates were 49 per 100,000 non-Hispanic blacks, 40 per 100,000 non-Hispanic whites, and 32 per 100,000 Asian Americans and Pacific Islanders (Siegel, Miller et al. 2017). The magnitude of the disparity in mortality rates was much greater. Between 2010 and 2014, CRC death rates were 21 per 100,000 non-Hispanic blacks, 15 per 100,000 non-Hispanic whites, and 10 per 100,000 Asian Americans and Pacific Islanders (Siegel, Miller et al. 2017). The higher rates for non-Hispanic blacks can be explained by disproportionately low socioeconomic status, which is associated with a higher risk of CRC incidence and death (Doubeni, Laiyemo et al. 2012, Grzywacz, Hussain et al. 2017). Low socioeconomic status can be defined based on several measures: the highest grade or level of schooling completed (less than high school diploma), job status (unemployed or in a managerial position), income below the federal poverty level, reliance on public assistance, lack of personal transportation, or income below $30,000 (Doubeni, Laiyemo et al. 2012). The official poverty measure was developed in the 1960s in conjunction with President Lyndon Johnson's War on Poverty. Each September the U.S. Census Bureau releases an update on the national poverty rate based on data from the prior year (DeNavas-Walt, Proctor et al. 2014). The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine the number of Americans living in poverty. The official poverty definition uses money income before taxes and does not include capital gains or noncash benefits such as public housing, Medicaid, and food stamps (Mitra and Brucker 2017). The poverty rate for blacks was 22% in 2016, compared with 19% for Hispanics, 9% for non-

Hispanic whites and 10% for Asians (Siegel, Miller et al. 2017). About 37% of the socioeconomic disparity in CRC incidence is attributable to a higher prevalence of behavioral risk factors, such as obesity, unhealthy dietary patterns, physical inactivity, and smoking (Doubeni, Major et al. 2012); while more than 40% of the racial disparity in CRC incidence can be explained by differences in screening uptake (Lansdorp-Vogelaar, Kuntz et al. 2012). The greater mortality disparity can be explained by inequities in comorbidities, access to care and treatment (Coughlin, Blumenthal et al. 2016), and deferred follow-up of screening-detected abnormalities (Laiyemo, Doubeni et al. 2010, Partin, Gravely et al. 2017).

Table 2.1 Colorectal Cancer Incidence (2009-2013) and Mortality (2010-2014) Rates by Race, Ethnicity and Sex.

	Incidence		Mortality	
Overall	40.7		14.8	
	Men	Women	Men	Women
All persons	46.9	35.6	17.7	12.4
Non-Hispanic white	46.1	35.2	17.3	12.3
Non-Hispanic black	58.3	42.7	25.9	16.9
Hispanic	42.8	29.8	15.0	9.2
Asian Americans and Pacific Islanders	37.8	27.8	12.4	8.8
Native Americans and Native Alaskans	51.4	41.2	19.5	14.0

Note: Rate per 100,000 population

2.2 Colorectal Cancer Screening

Most cases of CRC occur in average-risk adults. Increasing age, male sex, and non-Hispanic black race are associated with increased CRC incidence (Siegel, Miller et al. 2017). Early detection of CRC through routine screening has been demonstrated to be effective in reducing the incidence of and mortality from this disease (Whitlock, Lin et al. 2008, Koretz 2016). The USPSTF strongly recommends screening for CRC beginning at the age of 50 and continuing until the age of 75 for individuals at average risk, indicating that there is high degree of certainty in the net benefit of screening for CRC (Whitlock, Lin et al. 2008, US Preventive Services Task Force 2016). Individuals who are at increased or high risk are generally recommended to receive colonoscopies and should begin receiving screenings earlier than the general population (Wong, Wong et al. 2015). The decision to screen for CRC in individuals aged 76 to 85 years should be an individual one, based on professional judgment and patient preference (US Preventive Services Task Force 2016). In this document, we will focus on average-risk individuals: those who are asymptomatic and who have no personal or family history of colorectal cancer (Lieberman, Ladabaum et al. 2016).

There are a number of screening tests available to detect early-stage CRC and prevent incident cases, including 1) flexible sigmoidoscopy every 5 years, 2) FIT-DNA every 1 or 3 years, 3) fecal occult blood test or fecal immunochemical testing every year, 4) CT colonography every 5 years, 5) flexible sigmoidoscopy every 10 years plus FIT every year, and 6) and colonoscopy every 10 years (US Preventive Services Task Force 2016). The USPSTF provided evidence that screening for CRC in adults aged 50 to 75 years reduces CRC mortality even though the various screening tests have differing levels

of evidence to support their effectiveness, as well as distinct strengths and limitations (US Preventive Services Task Force 2016). When compared with no screening, all CRC screening strategies are cost-effective, though there is disagreement as to which screening strategy is the most cost-effective (Patel and Kilgore 2015). The screening tests listed above are not presented in any preferred or ranked order; instead, the purpose of recommending them is to maximize the total number of people who are screened, which will have the greatest effect on reducing CRC mortality (Ransohoff and Pignone 2013, US Preventive Services Task Force 2016). The USPSTF recommends screening via any of the accepted methods, as any method of screening is better than no screening at all (US Preventive Services Task Force 2016).

Table 2.2 USPSTF Recommended Colorectal Cancer Screening Strategies

Screening Method	Screening Interval
Stool-Based Tests	
Guaiac-based fecal occult blood test (gFOBT)	Every year
Fecal immunochemical test (FIT)	Every year
FIT-DNA	Every 1 or 3 years
Direct Visualization/ Structural Exams	
Colonoscopy	Every 10 years
CT colonography	Every 5 years
Flexible sigmoidoscopy	Every 5 years
Flexible sigmoidoscopy with FIT	Flexible sigmoidoscopy every 10 years plus FIT every year

The USPSTF derived several estimates from modeling conducted by the Cancer Intervention and Surveillance Modeling Network (CISNET) and presented the estimated number of life years gained, CRC deaths averted, lifetime colonoscopies required, and resulting complications per 1,000 screened adults aged 50 to 75 years for each of the screening strategies (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). Across the different screening methods, colonoscopy showed the highest number of years gained and CRC deaths averted per 1,000 screened adults aged 50 to 75. On the other hand, colonoscopy had the highest lifetime colonoscopies required and the highest number of complications (gastrointestinal and cardiovascular events) of CRC screening and follow-up testing per 1,000 screened adults aged 50 to 75 (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). Gastrointestinal events involve perforations, bleeding, transfusions, paralytic ileus, nausea and vomiting, dehydration, and abdominal pain (van Hees, Zauber et al. 2014, Knudsen, Zauber et al. 2016). Cardiovascular events include myocardial infarction, angina, arrhythmia, congestive heart failure, cardiac or respiratory arrest, syncope, hypotension, and shock (van Hees, Zauber et al. 2014, Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). A previous study has examined the differential harms of colonoscopy by age group and found increasing rates of serious adverse events from colonoscopy with increasing age (Lin, Piper et al. 2016).

The benefits and risks of different screening options vary (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016), but from a clinical perspective, colonoscopy is the preferred screening method, because a colonoscopy allows doctors to

examine the entire length of the colon and remove all cancers and precancerous polyps during the same procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016, Benard, Barkun et al. 2018, Duarte, Bernardo et al. 2018). Colonoscopy is also recommended as a follow-up when another CRC screening is positive. Moreover, colonoscopy is validated in a randomized trial as having a mortality benefit (Patel and Kilgore 2015, Koretz 2016, US Preventive Services Task Force 2016).

A colonoscopy remains the most commonly recommended test since it has the ability to detect polyps throughout the entire colon lumen (Wolf, Basch et al. 2016). It also has the advantage of not needing to be repeated for 10 years (US Preventive Services Task Force 2016). However, patients must meet several requirements before receiving a colonoscopy, such as bowel preparation, a facility visit, and a pre-procedure specialty office visit (Cheng, Huang et al. 2017). An adequate bowel preparation is needed in order for the doctors to view the colon clearly. Inadequate bowl preparation has been shown to decrease the adenoma detection rate (Sherer, Imler et al. 2012, Brimhall, Hankins et al. 2016). It requires taking medication that causes diarrhea to empty the colon (Cheng, Huang et al. 2017). Furthermore, sedation is designed to depress an individual's level of consciousness and to provide anxiolysis, amnesia, and analgesia. Therefore, colonoscopy requiring a day away from work and a chaperone to provide transportation (Wolf, Fontham et al. 2018). Polyps can be removed by passing a wire loop through the colonoscope either to cut the polyp from the wall of the colon, or demolish it in place using an electric current (Levin, Lieberman et al. 2008). Use of flexible sigmoidoscopy and fecal occult blood test have considerably declined in the past two decades in favor of colonoscopies (Phillips, Liang et al. 2007, Fenton, Cai et al. 2008, Schenck, Peacock et

al. 2009, Klabunde, Cronin et al. 2011), a fact which may be partly attributed to growing reimbursement for average-risk colonoscopies, physician preferences and referral patterns (Harewood and Lieberman 2004, Ransohoff 2005, Duarte, Bernardo et al. 2018). In 2012, 62% of all adults aged 50 to 75 who were screened for CRC received a colonoscopy versus other modalities, with fecal occult blood test coming in second at 10% (Centers for Disease Control and Prevention 2013). However, colonoscopies miss around 10% of significant lesions in expert setting and are more costly on a one-time basis than any other screening test (Meester, Doubeni et al. 2015). In addition, many individuals do not want an invasive test or a test that requires bowel preparation (Inadomi, Vijan et al. 2012, Cheng, Huang et al. 2017). Moreover, colonoscopies involve a wider variation in quality and higher potential for patient injury than any other screening test (Rembacken, Hassan et al. 2012, Pinto-Pais 2017, Rex and Ponugoti 2017). Finally, access may be limited by insurance status and local resources (Joseph, Meester et al. 2016). Therefore, providers should consider patient preference and test availability when making CRC screening recommendations and offering choices. Shared decision making can also improve adherence (Inadomi, Vijan et al. 2012, Wolf, Fontham et al. 2018).

Flexible sigmoidoscopy is an endoscopic procedure that examines the lower half of the colorectal lumen. A simple bowel preparation is needed before the examination (Wolf, Fontham et al. 2018). If a pre-cancerous adenoma or colorectal cancer is found, a follow-up colonoscopy will be required to examine the entire colon (Niedermaier, Weigl et al. 2018). Flexible sigmoidoscopy is usually performed without sedation, thus requiring less time commitment than colonoscopy (Wolf, Fontham et al. 2018). Previous

RCTs have demonstrated that a single flexible sigmoidoscopy is a safe, well accepted, and effective screening method for the prevention of CRC (Atkin, Edwards et al. 2010, Segnan, Armaroli et al. 2011, Holme, Loberg et al. 2014, Atkin, Wooldrage et al. 2017). A recent 17-year follow-up of the UK Flexible Sigmoidoscopy Screening Trial reported a 26% reduction in the incidence of CRC and a 30% reduction in mortality (Atkin, Wooldrage et al. 2017).

CT colonography has been recommended by the American Cancer Society since 2008 and was added to the USPSTF guideline in 2016 (US Preventive Services Task Force 2016, Wolf, Fontham et al. 2018). CT colonography involves the acquisition of thin-slice computed tomography images that can be evaluated as two-dimensional images or reconstructed into three-dimensional images of the colorectal lumen (Wolf, Fontham et al. 2018). Bowel preparation is needed before the examination and follow-up colonoscopy is required to remove any abnormalities detected (Wolf, Fontham et al. 2018). According to a systematic review and meta-analysis study conducted by Lin and colleagues (2012), patients preferred CT colonography over colonoscopy. Limited bowel preparations for CT colonography may be the reason for this preference (Lin, Kozarek et al. 2012). Several studies reported that CRC detection rates with CT colonography were essentially identical to those achieved with colonoscopy (Pickhardt, Choi et al. 2003, Johnson, Chen et al. 2008). However, a systematic review of detection rates for advanced colorectal neoplasia (ACN) among asymptomatic patients showed that 6% of patients who received a CT colonography were diagnosed with cancer, while 9% who received a colonoscopy were diagnosed with cancer (Duarte, Bernardo et al. 2018). Duarte and colleagues concluded that CT colonography is an option for CRC screening in

asymptomatic patients, but because CT colonography is inferior in detecting ACN, it should not replace colonoscopy (Duarte, Bernardo et al. 2018).

Stool-based tests examine the stool for secondary signs of cancer such as bleeding or shedding of cells and are less invasive and less expensive than other options (Lieberman, Ladabaum et al. 2016). Stool-based tests do not require a bowel preparation. They can be completed in the privacy of the patient's home and do not require time off from work (Wolf, Fontham et al. 2018). However, Modeling studies suggest that the number of years of life saved through a high-quality stool-based screening strategy are similar to the outcomes of a high-quality colonoscopy screening strategy (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). The fecal occult blood test averted 22 CRC deaths per 1,000 screened adults aged 50 to 75, and the fecal immunochemical test averted 22 CRC deaths per 1,000 screened adults aged 50 to 75. During the same time period, Colonoscopy averted 24 CRC deaths per 1,000 screened adults aged 50 to 75 (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). All positive stool-based tests must be followed up with colonoscopy (Partin, Gravely et al. 2017, May, Yano et al. 2018).

FIT-DNA is a new test with limited data on screening outcomes (Lieberman, Ladabaum et al. 2016). FIT-DNA combines tests for stool DNA markers associated with cancer and adenomas with a FIT with published performance characteristics (Wolf, Fontham et al. 2018). This test can be done in the privacy of the patient's home and does not require time off work (Wolf, Fontham et al. 2018). Only one such test (called Cologuard) is currently available in the United States. It was approved by the U.S. Food and Drug Administration (FDA) in 2014 for screening men and women aged 50 or older

who have an average risk of CRC. Effective October 9, 2014, Medicare covered the stool DNA test with no co-insurance or Part B deductible for Medicare beneficiaries who are aged 50 to 85 and who have no symptoms of CRC or are at increased risk of CRC. FIT-DNA testing is covered by Medicare at three-year intervals, as it is considered an acceptable testing modality by USPSTF (US Preventive Services Task Force 2016). According to a large, manufacturer-funded, multicenter, comparative trial of DNA and FIT testing in average-risk individuals, the sensitivity of DNA testing for detecting colorectal cancer was 92%, and the sensitivity of FIT was 74%. The sensitivity for detecting advanced precancerous lesions was 42% with DNA testing and 24% with FIT. Moreover, specificities with DNA testing and FIT were 87% and 95%, respectively (Imperiale, Ransohoff et al. 2014). FIT-DNA is included in the American Cancer Society and USPSTF guidelines (US Preventive Services Task Force 2016, Wolf, Fontham et al. 2018). All positive tests must be evaluated by colonoscopy (Wolf, Fontham et al. 2018).

The mortality rate from CRC has been decreasing steadily since 1980 (Weir, Thompson et al. 2015, Siegel, Miller et al. 2017), a fact which partially may be attributable to removal of pre-cancerous, adenomatous polyps at an early stage based on diagnosis of CRC and widespread use of colonoscopy or other screening approaches (Cunningham, Atkin et al. 2010, Edwards, Ward et al. 2010, Lieberman 2010, Martin, Tully et al. 2017, Partin, Gravely et al. 2017). Nonetheless, self-reported CRC screening rates from the National Health Interview Survey are at 58%, and the National Committee for Quality Assurance (NCQA) indicates that only 60% of commercial and 69% of Medicare plan members aged 50 to 75 years received an appropriate CRC screening in 2016 (Paskett and Khuri 2015, White, Thompson et al. 2017). Moreover, BRFSS data

indicate that around 65% of adults aged 50 to 75 years reported having had one of the colorectal screening tests recommended by USPSTF, and around 60% of adults aged 50 to 75 years had received a colonoscopy within the past 10 years (Joseph, King et al. 2012, Liss and Baker 2014).

Table 2.3 Percentage of adults who received colorectal cancer screenings according to the recommended schedule, by selected sociodemographic characteristics and health care access – National Health Interview Survey, United States, 2015

Characteristics	N	%
Overall	12,650	62.4
Age group (years)		
50-64	7,947	57.9
65-75	4,703	71.8
Race		
White	10,051	63.7
Black	1,777	59.3
American Indian/Alaska Native	160	48.4
Asian	595	52.1
Ethnicity		
Non-Hispanic	11,163	64.2
Hispanic	1,487	47.4
Education		
Less than high school	1,681	46.7
High school graduate/GED	3,275	58.2
Some college/Associate degree	3,896	63.5
College graduate	3,754	70.7
Percentage of federal poverty threshold		
<139	2,702	46.9
139-250	2,432	56.1
250-400	2,455	62.6
>400	5,060	70.0
Health care coverage		
Private	7,628	65.6
Military	702	77.6
Public only	3,494	60.1
Uninsured	790	25.1

Note: Results for individuals aged 50-75 years who received a fecal occult blood test within 1 year, a sigmoidoscopy within 5 years and fecal occult blood test within 3 years, or a colonoscopy within 10 years

In 2010, the US Department of Health and Human Services (HHS) initiated HP2020, which covered several objectives for reducing cancer mortality. Each objective was assigned a baseline measure in 2007 and a target to be achieved by 2020. HP2020 calls for a 15% reduction in death rates from 2007 to 2020 for CRC (Weir, Thompson et al. 2015). Moreover, the National Colorectal Cancer Roundtable (NCCRT) initiated a goal to increase the CRC screening rate to 80% in the eligible population by 2018 (Karlitz, Oliphant et al. 2017). Achieving this goal would avert 280,000 new cases of CRC and 200,000 deaths from the disease by 2030, and 24.4 million people would be screened (Fedewa, Ma et al. 2015, Meester, Doubeni et al. 2015). Nonetheless, the aforementioned screening rates are lower than the use of preventive interventions for other screening-amenable cancers, below the 80% coverage of the CRC screening target, and below the HP2020 target of 71% (Swan, Breen et al. 2010, Karlitz, Oliphant et al. 2017, White, Thompson et al. 2017).

Previous studies have identified numerous barriers facing individuals who wish to receive CRC screenings, including barriers at the patient, provider, and health care system levels (McLachlan, Clements et al. 2012, Ramdass, Petraro et al. 2014, Bromley, May et al. 2015, Wang, Qiu et al. 2018).

These barriers include low educational attainment and literacy, gender (female), race (Hispanic or non-Hispanic black), embarrassment or fear concerning the procedure, concerns about the cost, comorbidities, and lack of health insurance (Meissner, Klabunde et al. 2012, Weiss, Smith et al. 2013, Hughes, Watanabe-Galloway et al. 2015, Knight, Kanotra et al. 2015, Zhao, Okoro et al. 2018). Meanwhile, having a higher income, being married, being at the upper end of the age-range screening guidelines, having a usual

source of care, and having an increased perceived risk of CRC are associated with increased CRC screening rates (Palmer, Midgette et al. 2010, James, Daley et al. 2011, Winterich, Quandt et al. 2011, Meissner, Klabunde et al. 2012, Wilkins, Gillies et al. 2012, Ruggieri, Bass et al. 2013, Ramdass, Petraro et al. 2014). Racial and ethnic disparities in CRC screening have been documented broadly; and most studies indicate a lower rate of screening among racial and ethnic minorities (Shih, Zhao et al. 2006, Burnett-Hartman, Mehta et al. 2016, Hong, Tauscher et al. 2017). Hong and colleagues (2017) also reported racial and ethnic disparities in CRC screening among Hispanics and Asian Americans (Hong, Tauscher et al. 2017). The Centers for Disease Control and Prevention (CDC) reported that racial and ethnic minorities were significantly less likely to receive colonoscopies within the recommended 10-year guidelines than non-Hispanic whites (Centers for Disease Control and Prevention 2013).

Being at the upper end of the age-range screening guidelines was associated with higher rates of CRC screening (Seeff, Nadel et al. 2004, Ellison, Jandorf et al. 2011, Centers for Disease Control and Prevention 2013, Ramdass, Petraro et al. 2014, White, Thompson et al. 2017). White and colleagues (2017) reported that individuals aged 65 to 75 years were significantly more likely to receive CRC screening than individuals aged 50 to 64 years (White, Thompson et al. 2017). Ellison and colleagues (2011) found that individuals aged 65 years or older were 2.17 times more likely to be receive CRC screening than individuals aged 50 to 64 years (Ellison, Jandorf et al. 2011). Ramdass and colleagues (2014) found that individuals aged 61 to 70 years and 71 to 80 years were significantly more likely to have received a screening colonoscopy in the past 10 years than individuals aged 50 to 60 years (Ramdass, Petraro et al. 2014). The CDC (2013)

reported that individuals aged 65 to 75 years were significantly more likely to have received a colonoscopy within the past 10 years than individuals aged 50 to 64 years (Centers for Disease Control and Prevention 2013). Seeff and colleagues (2004) found that individuals aged 60 to 69 were 1.87 times more likely to have received an endoscopy within the past 10 years than individuals aged 50 to 59 years, and individuals aged 70 to79 years were 2.12 times more likely to have received an endoscopy than those aged 50 to 59 years (Seeff, Nadel et al. 2004).

Marital status was associated with higher rates of CRC screening (Seeff, Nadel et al. 2004, Ellison, Jandorf et al. 2011, Grzywacz, Hussain et al. 2017). Ellison and colleagues (2011) found that married participants were 2.09 times more likely to receive CRC screenings than unmarried participants (Ellison, Jandorf et al. 2011). Wilcox and colleagues found that single participants were 0.65 times less likely to have a colonoscopy than other participants (Wilcox, Acuna et al. 2015). Seeff and colleagues (2004) found that unmarried participants were 0.86 times less likely to have received an endoscopy within the past 10 years than married participants (Seeff, Nadel et al. 2004).

There are also gender differences in CRC screening rates (Seeff, Nadel et al. 2004, Partin, Gravely et al. 2016). Men are significantly more likely to visit endoscopy clinics than women. Partine and colleagues (2016) found that women are less likely to have had an colonoscopy screening than men (Partin, Gravely et al. 2016). Ramdass and colleagues (2014) found that men were 2.71 times more likely than women to have had a screening colonoscopy in the past 10 years (Ramdass, Petraro et al. 2014). Seeff and colleagues (2004) found that women were 0.58 times less likely than men to have received an endoscopy within the past 10 years (Seeff, Nadel et al. 2004).

Individuals with lower household incomes and less education are less likely to have had a CRC screening (Courtney, Paul et al. 2013, Fedewa, Ma et al. 2015, Meyer, Allard et al. 2016, White, Thompson et al. 2017). Previous studies found a strong association between colonoscopy use and income, with higher income groups being associated with higher rates of colonoscopy use (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Solbak, Xu et al. 2018). Grzywach and colleagues (2017) found that individuals with lower income levels were less likely to have a sigmoidoscopy or colonoscopy than individuals with higher income levels (Grzywacz, Hussain et al. 2017).

Health insurance coverage is associated with CRC screening. Zhao and colleagues (2018) found that compared with persons who are adequately insured, those who are underinsured who were uninsured are less likely to receive CRC screening (Zhao, Okoro et al. 2018). White and colleague (2017) found that persons having any type of health insurance were more likely to receive CRC screening than those who had no insurance at all (White, Thompson et al. 2017). Individuals having health insurance were more likely to have received a colonoscopy within the past 10 years than those who had no health insurance (Centers for Disease Control and Prevention 2013). Individuals having private health insurance were 1.84 times more likely to receive colonoscopy screening than those without private health insurance (Courtney, Paul et al. 2013).

Residence location is associated with CRC screening (Meyer, Allard et al. 2016, Partin, Gravely et al. 2016, Wang, Qiu et al. 2018). People who live in rural or suburban settings are significantly less likely to receive CRC screening than people who live in city centers. More specifically, rural residents are 0.85 times less likely to receive CRC

screenings than urban residents (Meyer, Allard et al. 2016). Partin and colleagues (2016) showed that people who live in urban areas were 1.13 times more likely to miss colonoscopy than people who live in rural or highly rural areas (Partin, Gravely et al. 2016). Shih and colleague (2006) reported that people who live in the West were 1.24 times more like to have CRC screenings than people who live in the Northeast (Shih, Zhao et al. 2006).

Healthy lifestyles, including having other screening tests, exercising, eating large amounts of fruits and vegetables, and not smoking, were associated with higher rates of CRC screening (Seeff, Nadel et al. 2004, Sewitch, Fournier et al. 2007, Ellison, Jandorf et al. 2011, Grzywacz, Hussain et al. 2017). Ellison and colleagues (2011) found that individuals who had regular mammograms were 2.38 times more likely to receive CRC screening than those who did not (Ellison, Jandorf et al. 2011). Sewitch and colleagues (2007) found that individuals who received regular flu shots were 1.51 times more likely to receive endoscopies than those who did not (Sewitch, Fournier et al. 2007).

There was extensive evidence to support the impact of primary prevention strategies, primarily through lifestyle modification (Tarraga Lopez, Albero et al. 2014). Previous studies have indicated that avoidance of smoking and alcohol consumption, maintaining a healthy weight, and moderate physical activity are associated with markedly lower risks of CRC (Chan and Giovannucci 2010, Gong, Hutter et al. 2012, Crosara Teixeira, Braghiroli et al. 2014, Gong, Hutter et al. 2016). To achieve a significant reduction in CRC incidence, primary prevention is crucial complement to CRC screening. Smokers have an increased risk of receiving a diagnosis of an adenoma and higher risk of CRC-related death associated with current smoking (Gong, Hutter et

al. 2012, Tarraga Lopez, Albero et al. 2014). Previous studies found that individuals who engaged in any amount of vigorous activity were at lower risk of developing CRC than those who did not engage in this activity and regular physical activity cuts the risk of CRC by round 40% (Tarraga Lopez, Albero et al. 2014, Nunez, Nair-Shalliker et al. 2018).

These healthy lifestyles were also associated with higher rates of CRC screening (Seeff, Nadel et al. 2004, Sewitch, Fournier et al. 2007, Ellison, Jandorf et al. 2011, Grzywacz, Hussain et al. 2017). Individuals with moderate physical activity were 1.25 times more likely to have received an endoscopy within the past 10 years than those who had no significant physical activity (Seeff, Nadel et al. 2004). In addition, people who had exercised within the past 30 days were 1.25 times more likely to have had a sigmoidoscopy or colonoscopy than those who did not exercise (Grzywacz, Hussain et al. 2017).

With regard to healthy lifestyle habits, smoking status deserves particular attention. Sewitch and colleagues (2007) found that former smokers were 1.20 times more likely, and those who had never smoked were 0.84 times less likely to have received an endoscopy in the past 10 years than current smokers (Sewitch, Fournier et al. 2007). On the other hand, Seeff and colleagues (2004) found that current smokers were 0.82 times less likely to have received an endoscopy within the past 10 years than those who had never smoked. Meanwhile, Grzywach and colleagues (2017) found that current smokers were more likely to have had a sigmoidoscopy or colonoscopy than those who had never smoked (Grzywacz, Hussain et al. 2017).

The absence or presence of comorbidities is associated with CRC screening (Grzywacz, Hussain et al. 2017, Wang, Qiu et al. 2018). Grzywach and colleagues (2017) found that individuals with diabetes were 1.45 times more likely to have a sigmoidoscopy or colonoscopy than those without diabetes, and individuals with an activity limitation were 1.33 times more likely to have a sigmoidoscopy or colonoscopy than those with no limitation (Grzywacz, Hussain et al. 2017). Partin and colleagues (2017) found that individuals with low Charlson comorbidity scores were more likely to have colonoscopies than those with higher scores. More specifically, individuals with zero Charlson scores were 1.23 times more likely to have colonoscopies than individuals with Charlson scores ≥ 3 (Partin, Gravely et al. 2017). Wang and colleagues (2018) discovered that people who had chronic conditions were more likely to be up-to-date on CRC screenings than those who did not have chronic conditions (Wang, Qiu et al. 2018). Moreover, a perceived low or moderate CRC risk significantly increased a person's odds of being screened by colonoscopy when compared to those who had no unusual risk for CRC (Ramdass, Petraro et al. 2014). López-Charneco and colleagues (2013) found that individuals with perceived fair to poor health status were 1.17 times more likely to receive a sigmoidoscopy or colonoscopy within 5 years than individuals with perceived good to excellent health status (Lopez-Charneco, Perez et al. 2013).

Provider-level barriers to CRC screening included physician's gender, specialty, years in practice, lack of provider recommendation, lack of provider recognition of barriers, and lack of a regular provider (Holt, Shipp et al. 2009, James, Daley et al. 2011, Ruggieri, Bass et al. 2013, Ramdass, Petraro et al. 2014, Peterson, Ostroff et al. 2016). One of the most powerful factors in increasing adherence to CRC screening is provider

recommendation (Ramdass, Petraro et al. 2014, Peterson, Ostroff et al. 2016). A systematic review showed that provider recommendation significantly improves screening rates (Peterson, Ostroff et al. 2016). Furthermore, it has been found that offering patients a choice of CRC screening through shared decision making, rather than recommending a single test, can improve adherence to screening (Inadomi, Vijan et al. 2012, Wolf, Fontham et al. 2018). Ramdass and colleagues (2014) found that provider recommendation for a colonoscopy is the most effective strategy in promoting screening colonoscopies in the US (Ramdass, Petraro et al. 2014). In order for their screening recommendations to be figured into the NCCRT target rate of 80% and the HP2020 target of 71%, providers must recommend CRC screenings to all eligible individuals and provide follow-up to ensure their recommendations are followed. This is easier in some practice settings than others; for instance, large integrated health systems have systems in place to remind physicians and provide follow-up for recommendations (Potter, Ackerson et al. 2013). Thus system-level interventions could promote achieving the target 80% coverage of CRC screening and the HP2020 target of 71%. Moreover, outreach strategies whereby patients receive invitations to CRC screening via mail have demonstrated an increase in CRC adherence rates (Kempe, Shetterly et al. 2012, Gupta, Halm et al. 2013, Singal, Gupta et al. 2016).

Individuals having a regular physician or usual source of care were significantly more likely to receive CRC screening than those who did not (Ellison, Jandorf et al. 2011, Centers for Disease Control and Prevention 2013, Grzywacz, Hussain et al. 2017, White, Thompson et al. 2017). White and colleagues (2017) found that individuals having a regular provider were significantly more likely to receive CRC screening than

individuals who did not (White, Thompson et al. 2017). Ellison and colleagues (2011) found that individuals having a regular physician were significantly more likely to be CRC screening-adherent (Ellison, Jandorf et al. 2011). Grzywach and colleagues (2017) found that individuals having a personal doctor and health care provider were more likely to have a sigmoidoscopy or colonoscopy than those who did not (Grzywacz, Hussain et al. 2017). Seeff and colleagues (2004) found that individuals having a usual source of care were 1.77 times more likely to have received an endoscopy within the past 10 years than those who did not (Seeff, Nadel et al. 2004). The CDC reported that individuals having a regular provider were significantly more likely to have received a colonoscopy within the past 10 years than individuals who did not (Centers for Disease Control and Prevention 2013).

A few studies have found that female patients have a preference for female gastroenterologists for office visits and colonoscopies (Menees, Inadomi et al. 2005, Shah, Karasek et al. 2011, Chong 2012). The main reason for this sex preference was embarrassment, and a higher level of education was a significant factor in producing higher levels of patient embarrassment. Shah and colleagues (2011) confirmed that more than 30% of female patients would avoid receiving a colonoscopy if they were unable to have a physician of their sex preference (Shah, Karasek et al. 2011). Menees and colleagues (2011) also confirmed that 43% of female patients expressed preference for female colonoscopists; and of these, 87% would be willing to wait more than 30 days in order to access a female colonoscopist (Menees, Inadomi et al. 2005). Therefore, accommodating patient sex preference may improve adherence to CRC screening recommendations.

System-level barriers to CRC screening included the out-of-pocket cost, capacity, high numbers of uninsured, fewer specialist referrals, fewer interactions with a primary care physician (Palmer, Midgette et al. 2008, Holt, Shipp et al. 2009, Hatcher, Dignan et al. 2011, Lukin, Jandorf et al. 2012, Wilkins, Gillies et al. 2012, Joseph, Meester et al. 2016). A recent study reported that the estimated colonoscopy capacity was sufficient to screen 80% of the eligible U.S. population (Joseph, Meester et al. 2016). However, colonoscopies vary by quality, and high-quality colonoscopies take considerably more time than the average time physicians spend on colonoscopies (Vicari 2010, Keswani, Yadlapati et al. 2015, Bitar, Zia et al. 2018). Previous studies have demonstrated that physician supply has been associated with increased use of colonoscopy (Brouse, Wolf et al. 2008, Haas, Brawarsky et al. 2010, Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). Benarroch-Gampel and colleagues (2012) examined the influence of colonoscopist and primary care physician supply on racial disparities in receipt of colonoscopy and found that while increasing colonoscopist and primary care physician capacity was associated with increased colonoscopy use in whites, but it was associated with decrease in colonoscopy use in blacks and Hispanics (Benarroch-Gampel, Sheffield et al. 2012). An increased supply of providers may have little beneficial effect on race and ethnic disparities in the receipt of colonoscopies or on geographic disparities in the receipt of colonoscopies (Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). Interventions should focus on improving screening in populations living in rural areas and among minorities. If gastroenterologists are in short supply, alternatives may be considered in the short-run like training primary care providers to conduct colonoscopies (Selby, Cornuz et al. 2016).

Out-of-pocket costs may dampen patients' willingness to undergo CRC screening; and this is especially true for colonoscopies, which usually involve relatively high-cost sharing (Klabunde, Riley et al. 2004, Hamman and Kapinos 2015). In some areas, however, charges for the same services can differ more than tenfold, varying from roughly $500 to more than $8,000 (Lieberman and Allen 2015, Robinson, Brown et al. 2015). Pyenson and colleagues (2014) determined the costs related with colonoscopy in the commercial and Medicare populations and confirmed that the average allowed amount for a screening colonoscopy was $2,146 in the commercial population and $1,071 in the Medicare population, with average cost sharing of $334 the commercial population and $275 in the Medicare population (Pyenson, Scammell et al. 2014). Previous studies have shown that cost-sharing reduces preventative health care use, including the use of highly effective screening tests (Busch, Barry et al. 2006, Goodwin and Anderson 2012). One study examined the impact of eliminating coinsurance for colonoscopy and found that waiving coinsurance for colonoscopies resulted in an 18% increase in screening (Khatami, Xuan et al. 2012).

Beginning in September 2010, the ACA required all non-grandfathered private health plans to offer coverage of CRC screenings without cost-sharing to address the negative consequences of financial barriers on the use of preventative services and to promote CRC screening. Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, though not for therapeutic ones (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Therefore, Medicare beneficiaries may face unexpected out-of-pocket liabilities when a polyp is detected and removed during a

colonoscopy, in which case patients are billed a copay if diagnostic colonoscopy. Medicare beneficiaries are also responsible for Part B deductible and coinsurance when a colonoscopy is performed as part of a two-step screening process after another CRC screening is positive (Howard, Guy et al. 2014). This loophole may discourage the use of screening, so eliminating remaining loopholes for Medicare beneficiaries could improve screening rates.

The Removing Barriers to Colorectal Cancer Screening Act of 2017 (H.R. 1017/S. 479), sponsored by US Representatives Charlie Dent and Donald Payne, Jr., in the House of Representatives and Senator Sherrod Brown in the Senate, works to correct an oversight in current law that requires Medicare beneficiaries to cover the cost of their copayment for a free screening colonoscopy if a polyp is discovered and removed during the procedure (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Under current law, Medicare waives coinsurance and deductibles for colonoscopies. However, when a polyp is discovered and removed, the procedure is reclassified as therapeutic for Medicare billing purposes and beneficiaries become responsible for paying 20% coinsurance (Hamman and Kapinos 2015). This bill would eliminate costs for Medicare beneficiaries when a polyp is discovered and removed, ensuring that unexpected copays do not deter a patient from receiving screening (Howard, Guy et al. 2014). By eliminating financial barriers, this legislation would attain higher screening rates and reduce the incidence of and mortality from CRC. This bill received 277 combined co-sponsors in the 115th Congress.

2.3 Medicare Coverage of Colorectal Cancer Screening

Medicare is the federal health insurance program for people who are 65 or older (Altman and Frist 2015, Huffman and Upchurch 2018). It also covers younger adults with permanent disabilities and End-Stage Renal Disease. Medicare Part A (Hospital Insurance) covers inpatient hospital stays, care in a skilled nursing facility, hospice care, and some home care. Medicare Part B (Medical Insurance) covers doctor's services, outpatient care, medical supplies, and preventive services. Medicare Part C (Medicare Advantage Plans) is a type of Medicare health plan offered by a private company that contracts with Medicare. Medicare Part C provides all the benefits of Part A and Part B. Medicare Part D provides prescription drug coverage (Altman and Frist 2015).

Medicaid is a joint federal and state health insurance program providing need-based insurance to low-income children and adults, and many people are eligible for both Medicare and Medicaid. Roughly 10 million individuals are "dual eligible" for Medicare and Medicaid (Altman and Frist 2015).

Medicare is the largest payer for health care services in the United States and covers many preventive services, including colorectal cancer screening (Altman and Frist 2015). Today, Medicare Part B covers several types of CRC screening tests, including barium enema, colonoscopy, fecal occult blood test, multi-target stool DNA test, and flexible sigmoidoscopy (Howard, Guy et al. 2014). The Centers for Medicare and Medicaid Services (CMS) pays 100% of the charge for fecal occult blood tests, flexible sigmoidoscopies, colonoscopies, and multi-target stool DNA tests and 80% of the charge for barium enemas. However, when Medicare was first enacted in 1965, preventive

services were excluded (Lesser, Krist et al. 2011). At the time, there was no strong evidence presented from a randomized controlled trial to show that CRC screening was effective in reducing CRC incidence and mortality. Therefore, CRC screening was not reimbursed or widely practiced. However, after three RCTs in the mid-1990s suggested efficacy, a wide consensus developed.

The USPSTF made a decision to endorse CRC screening in 1996 and Medicare made a decision to reimburse for its use in 1998 (Ransohoff 2005). In 1998, Medicare provided for coverage of colorectal cancer screening procedures under Medicare Part B. Medicare covered (1) annual fecal occult blood tests (FOBTs); (2) flexible sigmoidoscopy over 4 years; (3) screening colonoscopy every 10 years for persons at average risk for colorectal cancer, or every two years for persons at high risk for colorectal cancer; (4) barium enema every 4 years as an alternative to flexible sigmoidoscopy, or every 2 years as an alternative to colonoscopy for persons at high risk for colorectal cancer; and (5) other procedures the Secretary finds appropriate based on consultation with appropriate experts and organizations. Effective January 1, 2004, Medicare extended the FOBT screening definition to provide for either one guaiac-based FOBT (gFOBT) or one immunoassay-based FOBT (iFOBT) at a frequency of every 12 months. Prior studies found that CRC screening rates increased after the Medicare coverage expansions, but screening rates remained below the recommended levels (Ko, Kreuter et al. 2005, O'Malley, Forrest et al. 2005, Gross, Andersen et al. 2006, Shih, Zhao et al. 2006, Ananthakrishnan, Schellhase et al. 2007, Fenton, Tancredi et al. 2009, White, Vernon et al. 2011). The persistently low screening rates, even after implementation of these policies, have led researchers to conclude that the financial costs

might not be an important barrier to CRC screening, and that they should advocate for new approaches (Stimpson, Pagan et al. 2012). However, these expansions in coverage left gaps; Medicare beneficiaries without supplemental insurance were responsible for up to 20% of the allowable charges, which may be the reason for the continued underuse of CRC screening.

On January 1, 2005, Medicare started covering a one-time initial preventive visit, known as the ‘‘Welcome to Medicare’’ visit (WMV). The preventive services were made available to new beneficiaries within six months of beginning their Part B coverage (Salloum, Jensen et al. 2013). The WMV provides an opportunity to review Medicare beneficiaries’ medical history, current health status, and risk factors, as well as to provide education, counseling, and referrals (Misra, Lloyd et al. 2018). Medicare’s regular cost-sharing provisions apply to the visit; that is, it is subject to the Medicare annual Part B deductible ($100) and a standard 20% Medicare copay above that amount. In 2008, Medicare waived its Part B deductible for colorectal cancer screening, and the screening was made available to new beneficiaries within 12 months of beginning their Part B coverage. However, until 2011, a beneficiary was still responsible for standard 20% Medicare copays (Salloum, Jensen et al. 2013). As a result of the ACA, Medicare waived its copays for the WMV, making this benefit free starting in 2011. Historically, only 3 – 6% of eligible beneficiaries get a WMV, even after changes extending benefit eligibility and waiving the annual deductible (Cuenca 2012, Ganguli, Souza et al. 2017). Recently, Misra and colleagues (2018) examined the impact of the ACA on WMV utilization and found that annual WMV rates began at 1% in 2005 and increased to 12% in 2016. The study indicated that the ACA provision was associated with significantly increased

utilization of WMV among newly enrolled Medicare beneficiaries (Misra, Lloyd et al. 2018).

In 2011, Medicare introduced the annual wellness visit (AWV) to provide an annual preventive health benefit to all Medicare beneficiaries who have been enrolled in Medicare Part B for at least 12 months. The AWV is free for beneficiaries and provides a regular opportunity to review each beneficiary's medical history, risk factors, and functional abilities (Ganguli, Souza et al. 2017). Based on current health status and risk factors, clinicians develop an individualized prevention plan that establishes preventive screenings and interventions, including colorectal cancer screening (Colburn and Nothelle 2018). Shen and colleagues (2017) reported that AWV utilization has increased over time, from 8% in 2011 to 20% in 2015 (Shen, Warnock et al. 2017).

The ACA required all non-grandfathered private health plans to offer coverage of CRC screenings without cost-sharing to address the negative consequences of financial barriers on the use of preventative services and to promote CRC screening. Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles and coinsurance for Medicare-approved CRC screenings. Moreover, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, though not for therapeutic ones (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Therefore, Medicare beneficiaries may face unexpected out-of-pocket liabilities when a polyp is detected and removed during a colonoscopy, in which case patients are billed a copay. Medicare beneficiaries are also responsible for Part B deductible and coinsurance when a colonoscopy is performed as part of a two-step screening process after another CRC screening is positive (Howard, Guy et al. 2014).

This loophole may discourage the use of screening, so eliminating remaining loopholes for Medicare beneficiaries could improve screening rates.

Table 2.4 Key Medicare Policy Changes for Colorectal Cancer Screening

Year	Policy	Who	Payment
1998	(1) annual FOBT; (2) flexible sigmoidoscopy over 4 years; (3) screening colonoscopy for individuals at average risk every 10 years, or for individuals at high risk every 2 years; (4) barium enema every 4 years	Part B	20% copay
2004	Extended annual immunoassay-based (iFOBT)	Part B	20% copay
2005	Welcome to Medicare: one-time initial preventive visit	New beneficiaries within 6 months	Part B deductible, 20% copay
2008	Extended Welcome to Medicare	New beneficiaries within 12 months	20% copay
2011	Extended Welcome to Medicare	New beneficiaries within 12 months	Free
2011	Annual Wellness Visit	Part B for at least 12 months	Free
2011	(1) annual FOBTs; (2) flexible sigmoidoscopy over 4 years; (3) screening colonoscopy for individuals at average risk every 10 years, or for individuals at high risk every 2 years; (4) barium enema every 4 years as an alternative to flexible sigmoidoscopy, or every 2 years for individuals at high risk;	Part B	Free, but 20% copay for barium enema and therapeutic colonoscopy
2014	Extended Multi-target stool DNA test for individuals at average risk every 3 years	Part B	Free

FIT-DNA is a new test and combines tests for stool DNA markers associated with cancer and adenomas plus a FIT with published performance characteristics (Wolf, Fontham et al. 2018). It was approved by the FDA in 2014 for screening men and women aged 50 or older with an average risk of CRC. Effective October 9, 2014, Medicare covered the stool DNA test with no co-insurance or Part B deductible for Medicare beneficiaries aged 50 to 85 who do not have symptoms of colorectal cancer or an increased risk of colorectal cancer. The test is covered by Medicare at three-year intervals, as it is considered an acceptable testing modality by USPSTF (US Preventive Services Task Force 2016). According to a large, manufacturer-funded, multicenter, comparative trial of DNA and FIT testing in average risk individuals, the sensitivity for detecting colorectal cancer is 92% with DNA testing and 74% with FIT. The sensitivity for detecting advanced precancerous lesions is 42% with DNA testing and 24% with FIT. Moreover, specificities with DNA testing and FIT are 87% and 95%, respectively (Imperiale, Ransohoff et al. 2014).

2.4 Conceptual Framework

Individuals who wish to receive CRC screenings face multiple barriers. Previous studies have identified the patient, provider, and health care system-level barriers to CRC screening (McLachlan, Clements et al. 2012, Ramdass, Petraro et al. 2014, Bromley, May et al. 2015, Wang, Qiu et al. 2018). In this study, we will focus on colonoscopy among the recommended CRC screening methods. Colonoscopy is the preferred screening

method, because a colonoscopy allows doctors to examine the entire length of the colon and remove all cancers and precancerous polyps in the same procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016, Benard, Barkun et al. 2018). However, one of the most significant barriers to CRC screening is out-of-pocket financial costs (Howard, Guy et al. 2014); and this is especially true for colonoscopies because of relatively high cost-sharing requirements (Klabunde, Riley et al. 2004, Hamman and Kapinos 2015). Therefore, it is critically important to know whether reduction of financial barriers can improve coverage of colonoscopies.

This study intended to identify the effects of cost-sharing reduction on the receipt of colonoscopies among the elderly as a result of ACA implementation. The analytical approach adopted for this analysis was the standard demand theory. Demand for colonoscopies is influenced by many factors. The major purpose of demand analysis for health care was to determine those factors which, on the average, most affect a person's utilization of health services. Demand analysis seek to identify which factors are most influential in determining how much care people are willing to purchase. Consumers purchase goods or services for their utility. If the commodity demanded by consumers is good health, then health can be produced by goods and services purchased in the market. Demand for medical care is derived from the more basic demand for health (Muurinen 1982).

According to Grossman (1972), the Demand for Health Model extended the human capital theory by explicitly incorporating health and recognizing that there are both consumption and investment reasons for investing in health (Grossman 1972). The basic characteristics of the model are (1) that health is a consumption commodity, so it

makes the consumer feel better; and (2) that health is an investment commodity, so a state of health is determined the amount of time available to the consumer of productivity (Grossman 1972).

Demand for colonoscopies can be explained using a number of factors, such as price, price of substitutes, age, gender, income, educational attainment, and other factors, indicating individual preferences and propensity to assume risks (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Courtney, Paul et al. 2013, Howard, Guy et al. 2014, Ramdass, Petraro et al. 2014, Hamman and Kapinos 2015, Partin, Gravely et al. 2016, Grzywacz, Hussain et al. 2017). Therefore, the demand function can be written as follows:

Demand for Colonoscopy= f (Price, Price of substitutes, Income, Age groups, Gender, Educational attainment, supply, Access, Other factors)

The standard demand theory states that, all other factors being equal, as the price of a good or service increases, demand for the good or service will decrease, and vice versa. The demand curve shows the relationship between the price of a product or service and the quantity of the product or service demanded. Price changes in colonoscopies lead to movements along demand curve (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Henry and colleagues (2007) conducted a cost analysis of colonoscopy using micro-costing and time-and-motion techniques to determine the total societal cost of colonoscopies, and they confirmed that the median direct health care cost for a

colonoscopy was $379 (Henry, Ness et al. 2007). Pyenson and colleagues investigated the cost of colonoscopy screening for average-risk individuals receiving Medicare, and they reported that the 2015 average Medicare colonoscopy screening costs of $1,035 (Pyenson, Pickhardt et al. 2015). Pyenson and colleagues (2014) determined the costs related with colonoscopy in the commercial and Medicare populations and confirmed that the average allowed amount for a screening colonoscopy was $2,146 in the commercial population and $1,071 in the Medicare population, with average cost sharing of $334 the commercial population and $275 in the Medicare population (Pyenson, Scammell et al. 2014). Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Therefore, demand for colonoscopies is expected to increase with cost-sharing reductions.

"Substitutes" means other goods or services which satisfy the same wants, or provide same characteristics, as something else. There are several substitutes that individuals can utilize instead of colonoscopies. A number of screening tests exist to detect early-stage CRC and prevent incident cases, including flexible sigmoidoscopy, FIT-DNA, fecal occult blood tests, fecal immunochemical tests, CT colonography, flexible sigmoidoscopy plus FIT, and colonoscopies (US Preventive Services Task Force 2016, Wolf, Fontham et al. 2018). The USPSTF recommends screening via an accepted method because any screening is better than no screening at all (Atkin, Edwards et al. 2010, Quintero, Castells et al. 2012, Patel and Kilgore 2015). Therefore, the price of

other CRC screening tests can affect demand for colonoscopies. If the price of other CRC screening tests increase, demand for colonoscopies is expected to increase.

According to the model (see figure 1), individuals inherit a stock of health when they are born. Health depreciates over time; however, an individual may able to slow this decline through an investment in health. As we age, our health stock depreciates faster; that is, the depreciation rate rises from δ_0 to δ_1 to δ_D. The result of aging in this model is a continuously falling optimal level of health stock. Age may also shift the marginal efficiency of investment (MEI) curve to the left, because the returns from an investment will last for a shorter period of time. This will reinforce the decrease in investment that occurs due to increased depreciation. As people's age advances, they experience an increase in the rate of illness and in the utilization of health services. The stock of health can be maintained by investments to sustain health, including use of colonoscopies. Over the life cycle, individuals will try to offset part of the increased rate of depreciation in their stock of health by increasing their expenditure on health. Therefore, demand for colonoscopies is expected to increase with aging. Previous studies have shown that being in the upper age-range of screening guidelines is associated with higher rates of screening colonoscopy (Centers for Disease Control and Prevention 2013, Ramdass, Petraro et al. 2014). Ramdass and colleagues (2014) found that individuals aged 61 to 70 years and 71 to 80 years were significantly more likely to have had a screening colonoscopy within the past 10 years when compared to individuals aged 50 to 60 years (Ramdass, Petraro et al. 2014).

Increased wage rates increase the returns obtained from days of good health. For example, if the wage rate increased to $20 from $15, 10 hours of work would bring in

$200 rather than $150. Therefore, higher wages imply a higher MEI curve, or MEI'. The higher wage will imply a higher optimal level of health stock in the pure investment model. The rewards of being healthy are greater for higher-wage workers, so increased wages will tend to increase workers' optimal health capital stock. It is now optimal to increase health stock from H_0 to H_2. If consumers' income increases, then any given price, the consumers are willing and able to purchase more goods or services. Therefore, the demand for colonoscopies will increase with increases in individuals' income. Benarroch-Gampel and colleagues (2012) showed that there was a strong association between colonoscopy use and income, with higher income groups associated with higher colonoscopy use (Benarroch-Gampel, Sheffield et al. 2012).

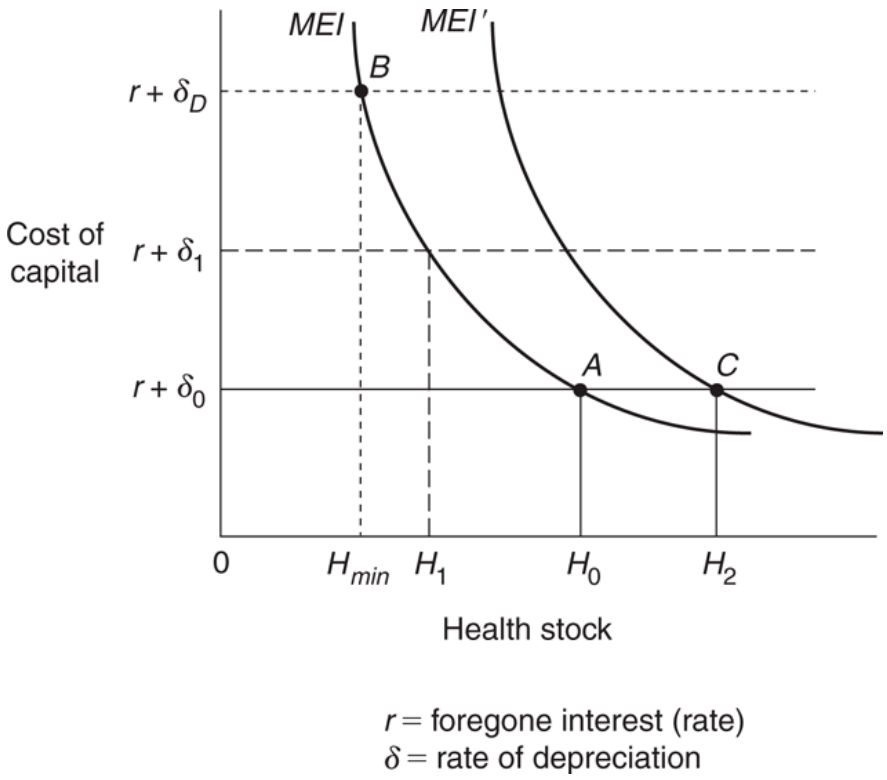

Figure 2.1. Optimal Health Stock

The effect of education is also illustrated in Figure 1. Here, the MEI curve shows the marginal efficiency of investment for the consumer with a low level of education, while the MEI' curve shows the same person with a higher level of education. Education raises the marginal product of the direct inputs; it reduces the quantity of these inputs required to produce a given amount of gross investment. Education is seen as improving the efficiency of producing health, which shifts the MEI curve to the right. More highly educated people will choose higher optimal health stocks, H_2, than will less educated people, who will choose H_0. On the other hand, highly educated individuals are also likely to recognize the benefits of improved health. They may also enjoy performing physical exercise or eating healthy food. They may recognize the effects of unhealthy lifestyles, including smoking cigarettes and drinking alcohol. They may enjoy feeling and looking good. As such, all else equal, educated individuals will have a greater taste for health relative to other goods. Therefore, the demand for colonoscopies is expected to increase with higher education. Previous studies have shown that individuals with higher levels of educational attainment are more likely to have had screening colonoscopy (Centers for Disease Control and Prevention 2013, Ramdass, Petraro et al. 2014).

Demand for colonoscopies is affected by gender. Previous studies have shown that being male is associated with higher levels of screening colonoscopy (Partin, Gravely et al. 2017). Partine and colleagues (2016) found that women are less likely to have had a colonoscopy screening than men (Partin, Gravely et al. 2016). Ramdass and colleagues (2014) found that men were 2.71 times more likely than women to have had a screening colonoscopy within the past 10 years (Ramdass, Petraro et al. 2014).

Demand for colonoscopies is affected by location of services. Previous study has shown that people who live in urban areas are 1.13 times more likely to miss colonoscopy than people who live in rural or highly rural areas (Partin, Gravely et al. 2016). Eberth and colleagues (2017) confirmed that there has been substantial growth over time in the number of facilities and physicians performing colonoscopies in South Carolina, although certain improvements have been limited to urban counties. For example, the number of gastroenterologists with a primary office location in rural South Carolina has declined by 13%, whereas urban counties experienced a 17% increase (Eberth, Josey et al. 2017).

Demand for colonoscopies is affected by factors determined by provider and supply of services. Previous studies have demonstrated that physician supply has been associated with increased use of colonoscopies (Brouse, Wolf et al. 2008, Haas, Brawarsky et al. 2010, Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). Benarroch-Gampel and colleagues (2012) examined the influence of colonoscopist and primary care physician supply on racial disparities in receipt of colonoscopy and found that while increasing colonoscopist and primary care physician capacity was associated with increased colonoscopy use in whites, but it was associated with decrease in colonoscopy use in blacks and Hispanics (Benarroch-Gampel, Sheffield et al. 2012). One of the most powerful factors in increasing adherence to CRC screening is provider recommendation (Ramdass, Petraro et al. 2014, Peterson, Ostroff et al. 2016). A systematic review has shown that provider recommendation significantly improves screening rates (Peterson, Ostroff et al. 2016).Researchers have also found that offering patients a choice of CRC screening through shared decision making, rather than recommending a single test, can improve adherence to screening (Inadomi, Vijan et al.

2012, Wolf, Fontham et al. 2018). Furthermore, provider recommendation has been associated with an increase in use of screening colonoscopy (Ramdass, Petraro et al. 2014). In fact, Ramdass and colleagues (2014) found that provider recommendation for colonoscopies is the most effective strategy to promote colonoscopy screening in the US (Ramdass, Petraro et al. 2014).

Demand for colonoscopies is affected by time and travel costs (Petryszyn, Kempinski et al. 2014). Higher time-cost effectively increases the price of the product. A colonoscopy requires a clinic visit. Henry and colleagues (2007) conducted a cost analysis of colonoscopies using micro-costing and time-and-motion techniques to determine the total societal cost of colonoscopies, including direct health care costs as well as direct non-health care costs, and costs related to patients' time (Henry, Ness et al. 2007). The median direct non-health care costs (travel costs and costs of caregivers' time) was $226, and indirect costs (related to patient time) was $274 (Henry, Ness et al. 2007). These time and travel costs may affect demand for colonoscopies. Frew and colleagues (1999) examined 3,525 respondents from 12 clinical centers in Great Britain that had carried out flexible sigmoidoscopy for CRC screening. 81% respondents traveled to the clinic by car, 9% by bus, 4% by taxi, and 2% by train; while 1% walked, and the remaining 4% came by other means or a combination of modes. Mean travel times for car and taxi users were significantly shorter than travel times for bus users and other modes combined. The mean travel cost amounted to $6.10 per person. Mean total time and travel cost was estimated for a subject as $16.90 and for a screening attendance as $22.40. By attending clinic-based screening, self-employed individuals lose their earnings, and that could effectively discourage them from receiving colonoscopies (Frew,

Wolstenholme et al. 1999). Moreover, Dong and colleagues (2011) assessed the patterns and reasons for missed work related to colonoscopy screenings and found that 34% of working individuals missed work more than one day when their screening was conducted on a Tuesday, Wednesday, or Thursday. They also found that 32% of workers took sick leave or vacation leave on the day prior to the colonoscopy, mainly in anticipation of the bowel preparation; 10% took sick or vacation leave the day after the colonoscopy, primarily as a precautionary measure following sedation rather than in response to true symptoms; and 9% took leave days both before and after the day of the colonoscopy. Moreover, colonoscopy procedures require a significant amount of time investment from friends and family members. 45% of individuals had friends or family members who also took leave time for the procedure (Dong, Kalmaz et al. 2011). Dong and colleagues suggested that these costs may be diminished through patient education about bowel preparation and what to expect before and after the procedure, and by scheduling more screening colonoscopies on Monday and Fridays (Dong, Kalmaz et al. 2011).

Demand for colonoscopies is affected by tastes and preferences. Previous studies have demonstrated that female patients have a preference for female gastroenterologists for office visits and colonoscopies (Menees, Inadomi et al. 2005, Shah, Karasek et al. 2011, Chong 2012). The main reason for this sex preference is embarrassment, and a higher level of education is a significant factor in patient embarrassment. Shah and colleagues (2011) confirmed that more than 30% of female patients would avoid receiving a colonoscopy if they were unable to have a physician of their sex preference (Shah, Karasek et al. 2011). Menees and colleagues (2011) also confirmed that 43% of female patients expressed preference for female colonoscopists; and of these, 87% would

be willing to wait more than 30 days to access a female colonoscopist (Menees, Inadomi et al. 2005). Therefore, patient sex preference may affect demand for colonoscopies. According to a systematic review and meta-analysis study conducted by Lin and colleagues (2012), patients preferred CT colonography over colonoscopy, and limited bowel preparations for CT colonography may be the reason for CT colonography preference (Lin, Kozarek et al. 2012).

Demand for colonoscopies is affected by quality of care. The benefit and risks of different screening options vary (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). The USPSTF detailed the estimated number of life years gained, CRC deaths averted, lifetime colonoscopies required, and resulting complications per 1,000 screened adults aged 50 to 75 for each of the screening strategies (Knudsen, Zauber et al. 2016, US Preventive Services Task Force 2016). Across the different screening methods, colonoscopies showed highest number of life years gained and CRC deaths averted per 1,000 screened adults aged 50 to 75. On the other hand, colonoscopies also had highest lifetime colonoscopies required and complications (gastrointestinal and cardiovascular events) of CRC screening and follow-up testing per 1,000 screened adults aged 50 to 75 years across the different screening methods (US Preventive Services Task Force 2016). Colonoscopies vary by quality, and high-quality colonoscopies take considerably more time than the average time physicians spend on colonoscopies (Vicari 2010, Keswani, Yadlapati et al. 2015, Bitar, Zia et al. 2018). The screening tests have differing levels of evidence supporting their effectiveness, as well as distinct strengths and limitations, and demand for colonoscopies will be affected by quality of care provided.

Demand for colonoscopies is affected by awareness level. Ricardo-Rodrigues and colleagues (2014) examined awareness levels of colonoscopies as a screening option for CRC, its uptake, and possible associated factors in confirmed individuals from lower socioeconomic groups or those who only had primary education or who showed a lower level of awareness (Ricardo-Rodrigues, Hernandez-Barrera et al. 2014). Hermann and colleagues (2015) argued that organized CRC screening groups should build a written invitation system to reduce the sociodemographic-related differential awareness and colonoscopy uptake (Hermann, Friedrich et al. 2015). Pelto and colleagues (2015) confirmed that health education and patient navigation programs that increase awareness of the benefits of colonoscopies may encourage colonoscopy completion. In the context of language-appropriate patient navigation programs for African-American and Latino/a individuals, those with lower incomes and English as a second language speakers may require additional education and counseling to support their decision-making about having colonoscopies (Pelto, Sly et al. 2015). Therefore, the demand for colonoscopies is expected to increase with higher awareness levels of colonoscopies.

Demand for colonoscopies is affected by time preference. Future costs and benefits must be discounted to put them on an equal basis with present values. Individuals with a high discount rate will be more likely to prefer projects with immediate payoffs rather than long-term projects. Both education and health require current outlays to gain distant payoffs. Individuals with lower discount rates will assign value to the future and will be more likely to invest in both education and health by receiving cancer screenings. Therefore, the demand for colonoscopies is expected to increase with lower discount rates.

Previous studies have confirmed that demand for colonoscopies is influenced by many factors, including price, price of substitute procedures, age, gender, income, educational attainment, and supply of providers (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Courtney, Paul et al. 2013, Howard, Guy et al. 2014, Ramdass, Petraro et al. 2014, Hamman and Kapinos 2015, Partin, Gravely et al. 2016, Grzywacz, Hussain et al. 2017). In this study, we examined how the ACA cost-sharing reduction has changed colonoscopy use among the elderly insured and assessed the various factors that affect receipt of colonoscopies.

2.5 Significance

Beginning in September 2010, the ACA required all non-grandfathered private health plans to offer coverage of CRC screenings without cost-sharing to address the negative consequences of financial barriers on the use of preventative services and to promote CRC screening. Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, though not for therapeutic ones (Howard, Guy et al. 2014, Hamman and Kapinos 2015). This study investigated the effect of the ACA's removing of financial barriers on the receipt of colonoscopies among insured elderly, who are predominantly covered by Medicare. Moreover, this study examined how income-related disparities in colonoscopy use have changed over the past decade and attempted to quantify various contributions to income-related disparity in the use of

colonoscopies among insured elderly. Our hypothesis was that the elderly insured population have a greater likelihood of undergoing colonoscopies following the implementation of the ACA. We also wanted to determine whether the ACA policy changes have helped the socioeconomically vulnerable elderly more than others.

Researchers and policy makers have studied the effects of cost-sharing reductions on the utilization of preventive health care in great detail, but surprisingly, only a few studies have assessed the effect of cost-sharing reductions on colonoscopies among elderly insured (including Medicare beneficiaries), following the implementation of the ACA (Hamman and Kapinos 2015, Cooper, Kou et al. 2016).

The few studies that examined this issue have used a very short time-frame beginning with the implementation of the ACA, so these studies may underestimate the effects of policy changes over time. Furthermore, these studies show varied results on the receipt of colonoscopies following the changes in coverage post-ACA (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Cooper, Kou et al. 2016); and they have not been able to determine whether eliminating financial barriers have helped the socioeconomically vulnerable Medicare beneficiaries more than other groups. It is true that some of the socioeconomically vulnerable elderly may be enrolled in Medicaid; in which case they would have received colonoscopies without any out-of-pocket expenses even in pre-ACA years. However, this should not affect the results significantly as almost all elderly are enrolled in Medicare and only a small percentage are enrolled in Medicaid (Medicaid only or dually eligible) (Grabowski 2012).

Five cycles (2008, 2010, 2012, 2014, and 2016) of the Behavioral Risk Factor Surveillance System (BRFSS) were utilized to examine the receipt of colonoscopies

among insured elderly aged 65 to 75 prior to the implementation of ACA and then again afterwards. Previous studies, using BRFSS from the years 2008, 2010, and 2012, has assessed the effect of cost-sharing reduction on colonoscopies among Medicare beneficiaries following the implementation of the ACA (Hamman and Kapinos 2015). One study used BRFSS to examine trends in breast and CRC screening in the U.S. by race, healthcare coverage, and socio-economic status before the Great Recession (2003-2005), during the recession (2007-2009), and at the beginning of the ACA period (2010-2012) (Wyatt, Pernenkil et al. 2017). Both these studies used a very short time frame beginning with the implementation of the ACA, so the studies may underestimate the effects of policy changes.

This study will contribute to advancing knowledge about the effect of reduction in cost-sharing on the receipt of colonoscopies among the elderly insured. It is critically important to know whether reduction of financial barriers alone can improve adherence to CRC screenings in order to achieve the national goal of 80% by 2018 target and the HP2020 goal of 71%. Reduction in financial expenses alone may not be enough to reach the goal, in which case these analyses will be able to indicate other policy options for improving coverage of colonoscopies. The study will provide scientific evidence on effect of cost-sharing reduction on the receipt of colonoscopies among the elderly insured as well as other policy options for improving adherence to CRC screening.

Under current law, Medicare waives coinsurance and deductibles for colonoscopies. However, when a polyp is discovered and removed, the procedure is reclassified as therapeutic for Medicare billing purposes; and beneficiaries become responsible for paying 20% coinsurance. Therefore, Medicare beneficiaries may face

unexpected out-of-pocket liabilities when a polyp is detected and removed during a colonoscopy. The Removing Barriers to Colorectal Cancer Screening Act of 2017 (H.R. 1017/S. 479) is designed corrected this oversight in current law, but it has yet to become a formal law. The study will provide supportive evidence to show the benefits of cost-sharing reductions receipt of colonoscopies among Medicare beneficiaries.

CHAPTER 3

METHODOLOGY

This study aimed to examine the changes in colonoscopy use among the elderly insured population, including Medicare beneficiaries, following the implementation of the ACA policy for preventive services. Our hypothesis was that the elderly insured population have a greater likelihood of undergoing colonoscopies following the implementation of the ACA. We also wanted to determine whether the ACA policy changes have helped the socioeconomically vulnerable elderly more than others. The first manuscript of the dissertation examined the effect of the ACA cost-sharing reduction on the receipt of colonoscopy among the elderly insured population. This study aimed to examine how the ACA cost-sharing reduction has changed colonoscopy use among the elderly insured and to assess the various factors that affect the receipt of colonoscopies. The second manuscript examined how disparities in colonoscopy use in the United States have changed over the past decade, in line with the implementation of the ACA and attempted to quantify the contributions to the disparity in the use of colonoscopies among elderly insured.

3.1 Methods for Manuscript 1

3.1.1 Data and participants

This study used 2008-2016 BRFSS data, an annual, nationally representative survey implemented in the United States, the District of Columbia, Puerto Rico, Guam, the US Virgin Islands, American Samoa, and Palau. BRFSS uses random-digit telephone dialing methods to sample noninstitutionalized adults aged 18 years or older (Kirchhoff, Lyles et al. 2012, Schneider, Clark et al. 2012). The BRFSS is the largest ongoing public health survey in the world; in 2016, the number of completed interviews was 486,303. The objective of BRFSS is to collect uniform, state-specific data on health risk behaviors, chronic diseases and conditions, access to health care, and use of preventive health services in the United States.

In 2011 BRFSS added cellular telephone households to adjust for the rapidly rising percentage of individuals and households in the US with cellular telephones but no landlines. BRFSS also adopted new methods of weighting to adjust survey data for differences between the demographic characteristics of respondents and target populations. Therefore, these two considerations were implemented during the fielding of the 2011 BRFSS. Since 2011, a new methodology called iterative proportional fitting ("raking") replaced the poststratification method to weight BRFSS data (Centers for Disease Control and Prevention 2012). Raking permits incorporation of cellular telephone survey data and allows the introduction of additional demographic characteristics in addition to age-race/ethnicity-gender that improves the degree and extent to which the BRFSS sample properly reflects the socio-demographic make-up of

individual states. Preliminary assessments show that the inclusion of cellular telephone respondents and the change to a new method of weighting may increase prevalence estimates for health risk behaviors and chronic disease in many states. Although raking might cause state prevalence trends for certain risk factors to shift upward, in general, the shape of trend lines over time may not be significantly affected (Centers for Disease Control and Prevention 2012).

In 2008 the BRFSS began including questions about colonoscopies in even years. Therefore, this study used data from the years 2008, 2010, 2012, 2014, and 2016. Previous studies, using BRFSS from the years 2008, 2010, and 2012, has assessed the effect of cost-sharing reduction on colonoscopies among Medicare beneficiaries following the implementation of the ACA (Hamman and Kapinos 2015). One study used BRFSS to examine trends in breast and CRC screening in the U.S. by race, healthcare coverage, and socio-economic status before the Great Recession (2003-2005), during the recession (2007-2009), and at the beginning of the ACA period (2010-2012) (Wyatt, Pernenkil et al. 2017). Both these studies used a very short time frame beginning with the implementation of the ACA, so the studies may underestimate the effects of policy changes. The sample for this study consists of noninstitutionalized, insured elderly aged 65 to 75 who participated in the survey. For our analyses, only those insured who were in the age group 65 to 75 years were included, bringing the sample size down to 446,981 adults. We excluded individuals with missing values for variables of interest and those who refused to answer questions relevant in creating the main measures for the study. Thus, the analysis sample consisted of 349,899 participants (144,628 men and 205,271 women) aged 65 to 75 years. Figure 3.1 shows the sample size after exclusion of missing

cases. Table 3.1 presents a study of the analysis sample of 349,899 participants, aged 65 to 75 years, as compared to the overall U.S. Medicare population.

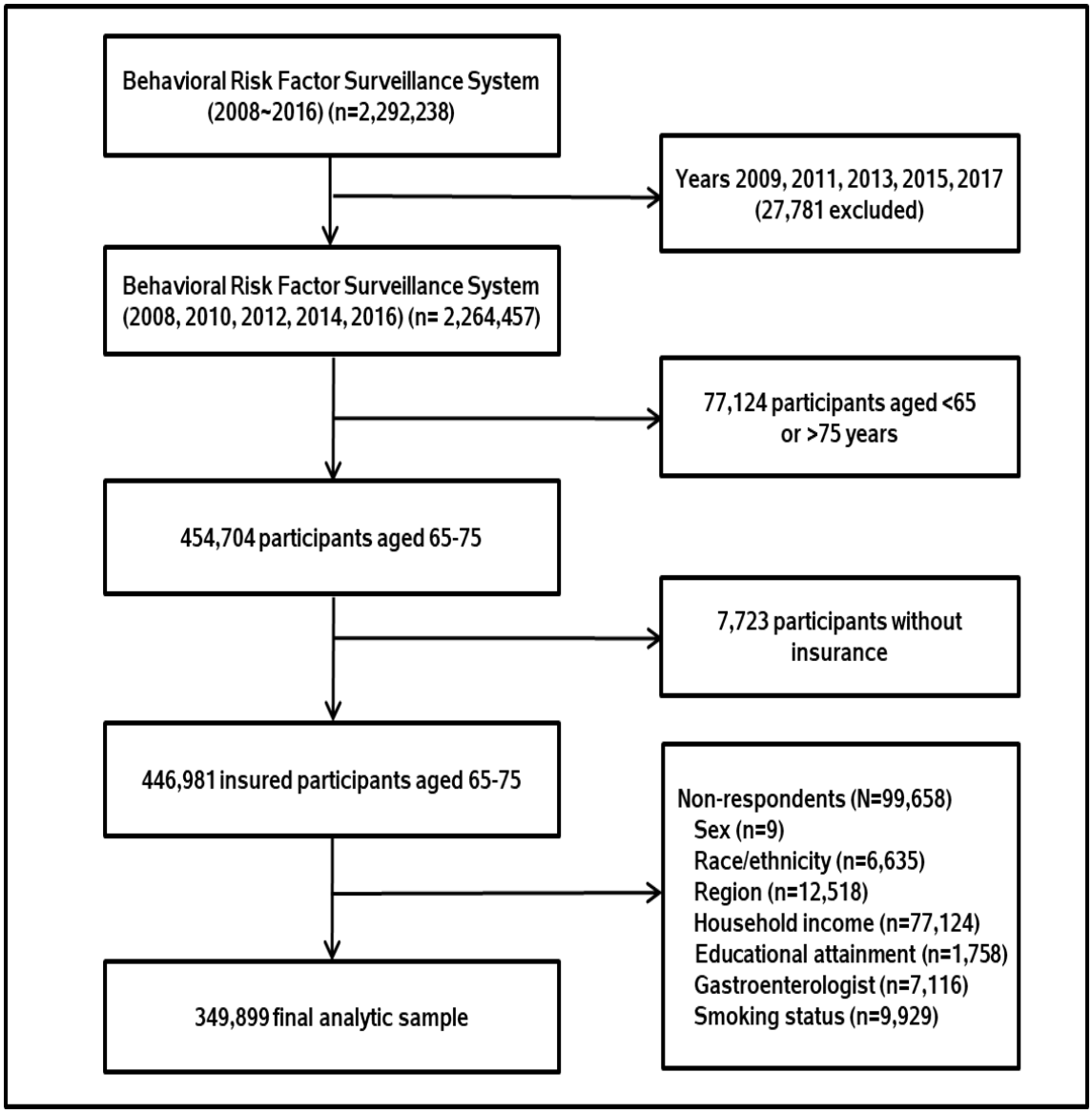

Figure 3.1 BRFSS sample, the exclusion criteria, and the final sample included in the analysis

Table 3.1 BRFSS sample compared to the overall U.S. Medicare population

Characteristic	BRFSS sample %	Characteristic	Medicare %
Total	**100**	**Total**	**100**
Age (years)		**Age (years)**	
65-66	23	<65	17
67-68	21	65-74	46
69-70	19	75-84	25
71-72	16	85+	13
73-75	22		
Sex		**Sex**	
Male	48	Male	46
Female	52	Female	54
Race/ethnicity		**Race/ethnicity**	
Non-Hispanic White	79	Non-Hispanic White	75
Non-Hispanic Black	9	Non-Hispanic Black	9
Hispanic	7	Hispanic	10
Other	5	Other	6
Region of Residence		**Region of Residence**	
Northeast	18	Urban	77
Midwest	22	Rural	23
South	38		
West	22		
Household income		**Household income**	
Less than $15,000	10	Below poverty	16
$15,000 to less than $25,000	19	100-125% of poverty	8
$25,000 to less than $35,000	14	125-200% of poverty	20
$35,000 to less than $50,000	18	200-400% of poverty	30
$50,000 or more	39	Over 400% of poverty	25
Education		**Education**	
Did not graduate high school	12	Did not graduate high school	20
Graduated High School	30	Graduated High School	27
Attended College	28	Some colleague or more	52
Graduated from College	29		
General health status		**General health status**	
Excellent/ Very good	46	Excellent/ Very good	45
good/ fair	47	good	47
Poor	7	Fair/Poor	8

Source: MedPAC analysis of the Medicare Current Beneficiary Survey, Cost and Use file 2013

Most Medicare beneficiaries are female and White. More precisely, 54% of the Medicare population is female and 52% of the BRFSS sample population was female. 75% of the Medicare population is non-Hispanic White and 79% of the BRFSS sample population was non-Hispanic White. 26% of the Medicare population have no high

school diploma, but the BRFSS sample showed that 12% of elderly insured have no high school diploma. Most beneficiaries reported fair to excellent health. Only 8% of the Medicare population reported poor health; similarly, only 7% of the BRFSS sample population reported poor health. The BRFSS sample from 2010 to 2016 showed that only 13% of elderly insured have an any types of cancer of any type. However, since there is no cancer information in is available for 2008, we did not include a cancer status variable as a covariate.

3.1.2 Variables needed for analyses

Dependent variables

The outcome of interest in our study is the self-reported receipt of colonoscopies in the previous 10 years. In this study, we will focus on the choice of colonoscopy as opposed to other recommended CRC screening methods. Colonoscopy is the preferred screening method because a colonoscopy allows doctors to examine the entire length of the colon and remove all cancers and precancerous polyps in a single procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016, Benard, Barkun et al. 2018). A respondent is considered to have received a colonoscopy if he or she answered "colonoscopy" to the question, "was your last test a sigmoidoscopy or colonoscopy?". To determine the years within which the colonoscopy was received, the responses to the following question was used: "How long has it been since you had your last sigmoidoscopy or colonoscopy?". We defined our first outcome variable as a

dichotomous measure of whether an individual was up-to-date with the USPSTF screening recommendation. During our study period, the guideline recommended a colonoscopy be performed once within the previous 10 years. Figure 3.2 shows the conceptual framework for the current study.

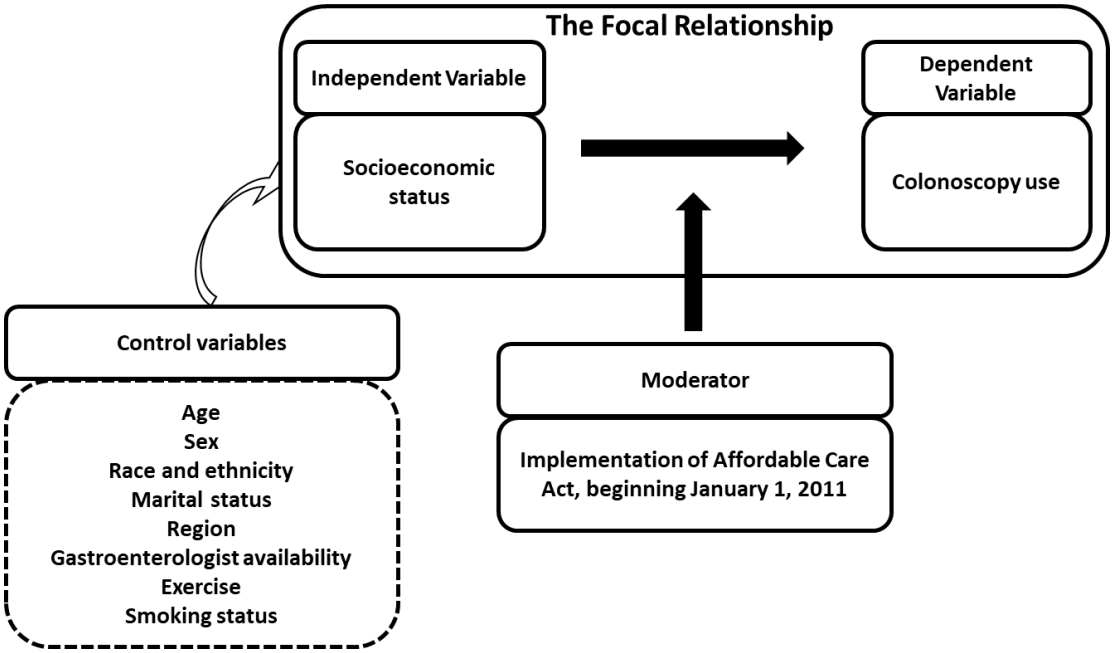

Figure 3.2 Conceptual framework for the current study.

Independent variables

Based on previous studies (Benarroch-Gampel et al., 2012; Cooper et al., 2016; Hamman & Kapinos, 2015(Ramdass, Petraro et al. 2014)), our analysis included demographic variables (age, sex, race and ethnicity, marital status, and region of residence) as possible covariates explaining receipt of colonoscopy. Age is classified into

five categories: 65-66; 67-68; 69-70; 71-72; and 73-75. Sex is classified into two categories: male and female. We have incorporated a race and ethnicity variable using the following discrete categories: non-Hispanic white, non-Hispanic Black, Hispanic, and other. Marital status is classified into two categories: married and other (divorced, widowed, separated, never married, and unmarried couple). Region of residence is classified into four broad geographic regions of the country based on FIPS codes: Northeast, Midwest, South, and West.

We included two socioeconomic variables in the model as well (household income and educational attainment). Household income has been reported using the following income classes: lower than $15,000; $15,000 to $25,000; $25,000 to $35,000; $35,000 to $50,000; and higher than $50,000. Educational attainment is grouped into four categories: did not graduate high school; graduated high school; attended college; and graduated from college.

We pooled all five cycles of the survey into one large data set. The data set includes individual surveys conducted in two years prior to the ACA policy change (2008 and 2010) and three years after (2012, 2014, and 2016). Medicare, the predominant insurance provider among elderly, waived deductibles for colonoscopies and eliminated coinsurance requirements effective January 1, 2011. To capture the effect of policy change on the receipt of colonoscopies, a policy-shift dummy variable was introduced into the model.

We used geographic availability of gastroenterologists and degree of health awareness of surveyed individuals as possible covariates affecting the receipt of

colonoscopies. The American Medical Association (AMA) Health Workforce Mapper reports the availability of different specialists by state, and we have used the reported number of professionally active gastroenterologists (GI) by state to calculate the geographic availability of GIs per 1000 individuals in a given population. We reported the geographic availability of gastroenterologists as a quartile of gastroenterologist availability, meaning we divided the distribution of the variable into four groups having equal frequencies. The hypothesis was that receipt of colonoscopies will be affected by the availability of colonoscopy providers in the area. Previous studies have demonstrated that physician supply has been associated with increased use of colonoscopy (Haas, Brawarsky et al. 2010, Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). A recent study reported that the estimated colonoscopy capacity was sufficient to screen 80% of the eligible U.S. population (Joseph, Meester et al. 2016).

BRFSS does not have any direct measure of individuals' awareness of colonoscopy as a screening option or the importance assigned by individuals to preventive services which have little or no current benefits but improve future health. One of the concerns in estimating the effect of a policy change over many years is that during that time, individuals may become more aware of the importance of colonoscopies, as well as other preventive services. Over the years, the awareness level may improve due to on-going campaigns to popularize the use of colonoscopies as an effective approach in preventing CRC. If we assume that knowledge about all preventive services are interrelated, "effective" use of one or more preventive actions will imply improvements in knowledge about the importance of colonoscopies. We have decided to use two proxy measures for this purpose: participation in physical exercise and smoking

status. Adoption of physical exercise reflects an individual's willingness to accept a preventive activity to improve health in the future. Since participation in physical exercise represents individual's willingness to spend resources (time and energy) now for the betterment of health in the future, it may be considered an indirect measure of the degree of importance the individual assigns to other preventive services like colonoscopies. Smoking status is a more complex proxy measure, probably reflecting an individual's long-term perspective on future health status and the implicit time discount rate. Smokers are likely to discount future years at a much higher rate than non-smokers and former smokers. Those with lower time preference rates (lower discount rates) are more likely to adopt preventive interventions and screenings (Axon, Bradford et al. 2009, Bradford 2010). We differentiated the individuals in the sample as those who reported physical exercise within the past 30 days and those who did not. Smoking status was categorized into three groups: current smoker, former smoker, and never smoked.

3.1.3 Statistical analyses

Descriptive statistics were used to summarize participant characteristics and to report the number and percentage of participants for each of the variables. In addition, we reported the percentage of respondents who had a colonoscopy in the previous 10 years by pre- and post-ACA policy change. We reported the percentage change instead of actual change as the percentage change method more precisely depicts the changes in data over a period of time. Bivariate and multivariate logistic models were used to estimate the effects of reduction in cost-sharing the receipt of colonoscopies among elderly insured aged 65 to 75. The multivariate models adjusted the outcome variable for

demographic characteristics (age, sex, race/ethnicity, marital status, and region of residence), socioeconomic status (household income and educational attainment), geographic availability of gastroenterologists, health awareness proxies (exercise and smoking status), and the policy change shifter variable.

The empirical model is as follows:

The receipt of colonoscopy (Yij) = β_{0j} + β_{1j} (patient age) + β_{2j} (patient gender) + β_{3j} (patient race and ethnicity) + β_{4j} (patient marital status) + β_{5j} (region of resident) + β_{6j} (household income) + β_{7j} (educational attainment) + β_{8j} (gastroenterologist availability) + β_{9j} (Exercise) + β_{10j} (smoking status) + β_{11j} (policy change) + γ_{ij}

This model is estimated to reveal the association between Medicare's cost-sharing reduction provision and the receipt of colonoscopies among elderly insured aged 65 to 75. We hypothesize that, controlling for observable patient and area resource differences, elderly insured have a greater likelihood of undergoing colonoscopies following the implementation of ACA. The primary outcome is the receipt of a colonoscopy within the previous 10 years, defined as a dichotomous measure of whether an individual was up-to-date with the USPSTF screening recommendation. During our study period, the guideline recommended that one colonoscopy be completed within the past 10 years. We expected that elderly insured have a greater likelihood of undergoing colonoscopies following the implementation of the ACA. All statistical analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC, USA).

3.2 Methods for Manuscript 2

3.2.1 Data and participants

This study used 2008-2016 BRFSS data, an annual, nationally representative survey implemented in the United States, the District of Columbia, Puerto Rico, Guam, the US Virgin Islands, American Samoa, and Palau. BRFSS uses random-digit telephone dialing methods to sample noninstitutionalized adults aged 18 years or older (Kirchhoff, Lyles et al. 2012, Schneider, Clark et al. 2012). The BRFSS is the largest ongoing public health survey in the world; in 2016, the number of completed interviews was 486,303. The objective of BRFSS is to collect uniform, state-specific data on health risk behaviors, chronic diseases and conditions, access to health care, and use of preventive health services in the United States.

In 2008 the BRFSS began including questions about colonoscopies in even years. Therefore, this study used data from the years 2008, 2010, 2012, 2014, and 2016. Previous studies, using BRFSS from the years 2008, 2010, and 2012, have assessed the effect of cost-sharing reduction on colonoscopies among Medicare beneficiaries following the implementation of the ACA (Hamman and Kapinos 2015). One study using BRFSS examined trends in breast and CRC screening in the U.S. by race, healthcare coverage, and socio-economic status before the Great Recession (2003-2005), during the recession (2007-2009), and at the beginning of the ACA period (2010-2012) (Wyatt, Pernenkil et al. 2017). Both these studies used a very short time frame beginning with the implementation of the ACA, so the studies may underestimate the effects of policy

changes. The sample for this study consists of noninstitutionalized, insured elderly aged 65 to 75 who participated in the survey from the years 2008, 2010, 2012, 2014, and 2016. For our analyses, only those insured who were in the age group 65 to 75 years were included, bringing the sample size down to 446,981 adults. We excluded individuals with missing values for variables of interest and those who refused to answer questions relevant in creating the main measures for the study. Thus, the analysis sample consisted of 349,899 participants (144,628 men and 205,271 women) aged 65 to 75 years.

3.2.2 Definition of the Measures Used

The variable of interest for the study is the self-reported receipt of a colonoscopy in the previous 10 years. A respondent is considered to have received a colonoscopy if the individual answered "colonoscopy" to the question, "was your last test a sigmoidoscopy or colonoscopy?". To determine the years within which the colonoscopy was received, the responses to the follow-up question were used: "how long has it been since you had your last sigmoidoscopy or colonoscopy?". We defined our outcome variable as a dichotomous measure of whether an individual was up-to-date with the USPSTF screening recommendation. During our study period, the guidelines recommended having a colonoscopy once every 10 years.

The literature has identified several sets of variables to explain variations in colonoscopy use. We included age, sex, race and ethnicity. Age was categorized into five groups: 65-66, 67-68, 69-70, 71-72, and 73-75. Sex was classified into two categories: male and female. Participants' race and ethnicity was categorized into four groups: non-

Hispanic white, non-Hispanic Black, Hispanic, and other. We dichotomized marital status as married or not married. We described geographic characteristics by census region (Northeast, Midwest, South, and West). Based on previous studies (Benarroch-Gampel, Sheffield et al. 2012, Hamman and Kapinos 2015, Solmi, Von Wagner et al. 2015, Cooper, Kou et al. 2016), our analysis included household income and educational attainment. We used a categorical measure of annual household income with the following categories: lower than $10,000; $10,000 to $14,999; $15,000 to $19,999; $20,000 to $24,999; $25,000 to $34,999; $35,000 to $49,999; $50,000 to $74,999; and $75,000 or more. Educational attainment was classified into four categories: did not graduate high school; graduated high school; attended college; and graduated from college. Racial and ethnic disparities in CRC screening had already been broadly documented, and most studies found that individuals belonging to ethnic minorities were less likely to adhere to screening guidelines; lower socio-economic status (indicating dimensions such as income, education, and employment status) among ethnic minority groups is considered the most likely explanation for this finding (Shih, Zhao et al. 2006, Benarroch-Gampel, Sheffield et al. 2012, Burnett-Hartman, Mehta et al. 2016, Hong, Tauscher et al. 2017). In addition, lower educational attainment is associated with lower adherence to CRC screening guidelines (Gimeno Garcia 2012, Kobayashi, Wardle et al. 2014).

The final data set generated for this analysis includes two years of information prior to the implementation of ACA (2008 and 2010) and three years of information following the implementation of ACA (2012, 2014, and 2016). Since a large majority of this group is covered by Medicare, the policy changes adopted by Medicare should have

significant impact on the use of CRC. For controlling the time trade-off rates of individuals and willingness to spend resources for improving future health status, we incorporated two variables in the analysis: whether the individual exercised or not within previous 30 days and whether the individual is a current smoker, former smoker, or never smoked.

3.2.3 Concentration index

The concentration index has demonstrated its usefulness as a tool in measuring health sector disparities. The concentration index measures the degree of disparity in the utilization of various medical care services or outcomes. To estimate the concentration index, one variable must be used as the main metric to rank households on the basis of levels of living or socioeconomic status. We can use household income as the measure to calculate the concentration index in the use of colonoscopies. The standard concentration index (CI), denoted below by CI, can be written as follows:

$$CI = \frac{2}{n\mu}\sum_{i=1}^{n} y_i\, R_i \; - 1$$

where n is the sample size, y_i is healthcare utilization of individual i, μ is its mean and $R_i = \frac{i}{N}$ is the fractional rank of individual i in household income distribution. For a given $\mu > 0$, the maximum of the concentration index is when the poorest i individuals have a value of y_i equal to zero and the richest $n - \; i$ individuals have a value of y_i

equal to 1. In this case, the value of CI will be maximum at +1[1]. If the poorest person uses CRC screening and not anyone else, the CI will have the value of -1. If the richest person uses CRC screening and not anyone else, the CI will have the value of +1. If CI equals zero, then there is no income-related disparity in the distribution of CRC screening. As this analysis have used a binary response indicating whether or not a insured elderly had a recommended colonoscopy, normalized concentration index employing the Wagstaff decomposition method was applied (Wagstaff 2005). Standard errors for the normalized index correct for both autocorrelation and heteroscedasticity (Cai, Coyte et al. 2017).

$$CI_n = \frac{CI}{1 - \mu}$$

3.2.4 Statistical analyses

We first compared the difference in concentration index between the pre- and post-ACA periods. Decomposition analysis of the concentration index was used to determine the impact of a range of sociodemographic variables on any disparity in colonoscopy use. It was based on the partitioning of total disparity into the precise disparities observed by each individual regressor (van Doorslaer, Koolman et al. 2004). A logistic regression was applied with a linear estimation to allow for the correct decomposition. The following equation shows the linear estimation of the logistic results

[1] $CI = \frac{2}{n\mu}\sum_{i=1}^{n} y_i\, R_i \; - 1 = \frac{2}{(n-1)\mu}\sum_{i=1}^{n-1} y_i(=0)\, R_i \; - 1 + \frac{2}{(1)\mu}\sum_{i=n-1}^{n} y_i(=1)\, R_i \; = 0 - 1 + 2 = +1$

where β_k^n are the average partial effects of each variable (x) – yielding the likelihood of a screening colonoscopy (y).

$$y_i = \sum_k \beta_k^n x_i^k + \varepsilon_i$$

The following equation shows the decomposition analysis comprised of average partial effects of each x as well as their means and individuals concentration index. In this equation, the first expression shows the contribution of equivalized income, the second expression shows effect of other socio-demographic variables perceived to influence colonoscopy usage, and the final expression refers to the residual term.

$$\overline{CI}_n = \left(\frac{\beta_k \overline{x}_r}{\mu}\right) \overline{CI}_r \sum_k (\beta_k \frac{\overline{x}_k}{\mu}) \overline{CI}_k + \frac{GC_\varepsilon}{\mu}$$

We presented CIs prior to the ACA policy change (2008 and 2010) and after ACA implementation (2012, 2014, and 2016). We identified the largest determinant of disparity observed in pre-ACA years and post ACA years. Positive values of the overall CIs suggest that colonoscopy use was concentrated among individuals with higher household incomes. CIs were broken down by confounder and represented as contributions to the overall income-related disparity in the use of colonoscopies with percentage contributions in brackets. The percentage contribution is attained by dividing the absolute contribution by the overall income-related disparity. We included age, sex, race and ethnicity, marital status, household income, educational attainment, region of residence, exercise, and smoking status as possible determinants.

3.3 Ethical approval

This study was reviewed and deemed exempt by the Institution Review Board at the University of South Carolina (See Appendix).

3.4 Limitations

This study has several limitations. First, the BRFSS is based on self-reports, which may be subject to recall bias. True screening rates are more likely less than 50% for adults aged 50 or older (Paskett and Khuri 2015). Therefore, one challenge is establishing an accurate level of CRC screenings. However, this study was unable to perform a cross-check with medical records using current data (Ferrante, Ohman-Strickland et al. 2008, Schenck, Klabunde et al. 2008). Second, there is also the possibility of selection bias in this type of survey, as less healthy patients may not be included in the sample. Third, the BRFSS does not include information about actual out-of-pocket expenditures or other possible determinants of screening such as opportunity, cost of time or difficulty in scheduling colonoscopies. Fourth, this study could not distinguish between screening and diagnostic colonoscopies. Nonetheless, given the fact that around 40% of adults who should receive CRC screenings do not receive them (Joseph, King et al. 2012, Hamman and Kapinos 2015, Paskett and Khuri 2015), finding an increase in all types of colonoscopies as a result of the Affordable Care Act does suggest an improvement in CRC detection. Fifth, gastroenterologists are not only providers of colonoscopy and there are regional variations (Benarroch-Gampel, Sheffield

et al. 2012, Joseph, Meester et al. 2016). Sixth, there is also the possibility of historical threats to validity (e.g. increasing awareness over time and social norms in support of CRC). Seventh, this study could not assess awareness of CRC. Finally, in 2011 BRFSS changed its weighting methodology with the inclusion of cellular phone-only respondents. Cellular phone respondents are likely to be different from others in terms of age and risk of CRC. Therefore, this additional approach of selecting respondents may have affected the sample of 2011 compared to samples from the pre-2011 period.

CHAPTER 4

RESULTS

4.1 Manuscript 1

THE EFFECTS OF THE AFFORDABLE CARE ACT ON THE RECEIPT OF COLONOSCOPIES AMONG INSURED ELDERLY[2]

[2] Lee M. Khan MM. Brant HM. Salloum RG. Chen BK. The Effects of the Affordable Care Act on the Receipt of Colonoscopies among Insured Elderly. Preparing in *Am J Public Health.*

Abstract

Objectives: The Affordable Care Act (ACA) waived deductibles and eliminated coinsurance for colonoscopies for Medicare beneficiaries beginning in January 1, 2011. This study investigated the effect of the ACA's directive to remove the financial barriers on the receipt of colonoscopies among the elderly insured, who are predominantly covered by Medicare.

Methods: We used data from the 2008-2016 Behavioral Risk Factor Surveillance System (BRFSS), an annual, nationally representative survey, to examine the receipt of colonoscopies for two years prior to the implementation of the ACA (2008 and 2010) and three years after the change (2012, 2014, and 2016). Multivariate logistic regressions were estimated to examine the change in colonoscopy use before and after the ACA, adjusting for patient characteristics and availability of health care providers in the geographic region.

Results: Of 349,899 eligible elderly insured in the age group 65 to 75 years, 236,275 (67.2%) had received a colonoscopy in the previous 10 years. The receipt of colonoscopies increased from 63.5% in pre-ACA years to 69.2% in the post-ACA years (p<.001). Compared with the pre-ACA period, colonoscopy uptake during post ACA years shows an odds ratio of 1.15 (95% confidence limit [CI] = 1.08-1.22, p<.001) after adjusting for time dependent improvements in colonoscopies and other relevant factors.

Conclusions: Following the implementation of the ACA, a statistically significant increase in colonoscopy use was observed. This suggests that eliminating financial

barriers to access has improved the CRC screening rate, but achieving 80% coverage, the target rate, will require additional interventions to encourage higher levels of screenings.

Introduction

Colorectal cancer (CRC) is the second leading cause of cancer deaths for both men and women in the United States (Siegel, Miller et al. 2017). There were an estimated 135,430 new cases of and 50,260 deaths from CRC in 2017 (Siegel, Miller et al. 2017). Early detection of CRC, through routine screening, has been demonstrated to be effective in reducing the incidence of and mortality from this disease (Whitlock, Lin et al. 2008, Edwards, Ward et al. 2010, Siegel, Miller et al. 2017). The U.S. Preventive Services Task Force (USPSTF) strongly recommends screening for CRC beginning at the age of 50 years and continuing until the age of 75 years for individuals at average risk, implying that increases in screening for CRC result in decreases of CRC mortality (Whitlock, Lin et al. 2008, Koretz 2016, US Preventive Services Task Force 2016).

USPSTF recommends a number of screening tests for use in detecting early-stage CRC and preventing incident cases, including 1) flexible sigmoidoscopy every 5 years, 2) FIT-DNA every 1 or 3 years, 3) fecal occult blood test or fecal immunochemical testing every year, 4) CT colonography every 5 years, 5) flexible sigmoidoscopy every 10 years plus FIT every year, and (6) colonoscopy every 10 years (US Preventive Services Task Force 2016). The USPSTF recommends screening using any of the accepted methods, as

any type of screening test would be better than no screening at all (Atkin, Edwards et al. 2010, Quintero, Castells et al. 2012, Patel and Kilgore 2015, US Preventive Services Task Force 2016). All the screening options are not equally attractive to all individuals; depending upon health history and preferences of individuals, the choices may differ significantly. However, from a clinical perspective, colonoscopy is the preferred method, because a colonoscopy allows doctors to examine the entire length of the colon and remove all cancers and precancerous polyps during a single procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016). Colonoscopy is also recommended as a follow-up when another CRC screening is positive. Moreover, colonoscopy has been validated in a randomized trial to have a mortality reduction benefit (Zauber, Winawer et al. 2012, Patel and Kilgore 2015, Koretz 2016, US Preventive Services Task Force 2016).

The mortality rate from CRC has decreased steadily since 1980 (Weir, Thompson et al. 2015, Siegel, Miller et al. 2017), which may be partially attributable to removal of pre-cancerous, adenomatous polyps at an early stage based on a diagnosis of CRC and widespread use of colonoscopies or other screening approaches (Cunningham, Atkin et al. 2010, Edwards, Ward et al. 2010, Lieberman 2010, Martin, Tully et al. 2017, Partin, Gravely et al. 2017). Nonetheless, the self-reported CRC screening rate in the National Health Interview Survey is at 58%, and the National Committee for Quality Assurance (NCQA) indicates that 60% of commercial and 69% of Medicare plan members aged received an appropriate CRC screening in 2016 (Paskett and Khuri 2015). Moreover, the Behavioral Risk Factor Surveillance System (BRFSS) indicates that around 65% of adults aged 50 to 75 years have undergone one of the colorectal screening tests

recommended by USPSTF, and around 60% of adults aged 50 to 75 years received a colonoscopy within the past 10 years (Joseph, King et al. 2012). These estimates are lower than the use of preventive interventions for other screening-amenable cancers, below the 80% coverage of the CRC screening target, and below the HP2020 target of 71% (Swan, Breen et al. 2010, Karlitz, Oliphant et al. 2017).

One potential barrier to CRC screening is the out-of-pocket financial costs associated with the screenings (Howard, Guy et al. 2014). The financial costs may significantly dampen patients' willingness to adopt any preventive procedures, including any of the CRC screenings. This is especially true for colonoscopies, which usually involved a relatively high cost-sharing requirement prior to the ACA policy changes in 2011 (Klabunde, Riley et al. 2004, Hamman and Kapinos 2015). Previous studies have shown that cost-sharing reduces preventive health care use, including the use of highly effective screening tests (Busch, Barry et al. 2006). One study found that waiving coinsurance for colonoscopies resulted in an 18% increase in screening (Khatami, Xuan et al. 2012).

To address the negative consequences of financial barriers on the use of preventive services and to promote CRC screening, the Affordable Care Act (ACA) required all non-grandfathered private health plans to offer coverage of CRC screening without cost-sharing. Consistent with the ACA policy requirement, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, though not for diagnostic ones (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Therefore, Medicare beneficiaries may face unexpected out-of-pocket liabilities when a polyp is detected and removed during a

colonoscopy, as these patients are billed a copay. Medicare beneficiaries are also responsible for Part B deductibles and coinsurance when a colonoscopy is performed as part of a two-step screening process after another CRC screening is positive (Howard, Guy et al. 2014). Nevertheless, the ACA policy change, in general, implies that the elderly insured population should see significant reductions in out-of-pocket expenses associated with colonoscopies.

Research on the effects of cost-sharing reductions on utilization of preventive health care has received significant attention from researchers and policy makers, but surprisingly, only a few studies have assessed the effect of cost-sharing reduction on colonoscopies among the elderly insured population (including Medicare beneficiaries) following the implementation of the ACA (Hamman and Kapinos 2015, Cooper, Kou et al. 2016). The few studies that have examined this issue have used a very short time frame beginning with the implementation of the ACA, so they may have underestimated the effects of the ACA cost-sharing reduction. Furthermore, the results of these studies vary regarding the receipt of colonoscopies following the changes in coverage post-ACA, (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Cooper, Kou et al. 2016) and they have not been able to determine whether eliminating financial barriers might have helped socioeconomically vulnerable Medicare beneficiaries more than other groups. However, some of the socioeconomically vulnerable elderly may be enrolled in Medicaid, in that case, these individuals would have received colonoscopy without any out-of-pocket expenses in the pre-ACA years. This should not affect the results significantly as almost all the elderly are enrolled in Medicare and only a small

percentage of the elderly are enrolled in Medicaid (Medicaid only or dually eligible) (Grabowski 2012).

To address these gaps in current research, this study aimed to examine the changes in colonoscopy use among the elderly insured population, including Medicare beneficiaries, following the implementation of the ACA policy for preventive services. Our hypothesis was that the elderly insured population have a greater likelihood of undergoing colonoscopies following the implementation of the ACA. We also wanted to determine whether the ACA policy changes have helped the socioeconomically vulnerable elderly more than others.

METHODS

This study used 2008-2016 BRFSS data, an annual, nationally representative survey implemented in the United States, the District of Columbia, Puerto Rico, Guam, the US Virgin Islands, American Samoa, and Palau. BRFSS uses random-digit telephone dialing methods to sample noninstitutionalized adults aged 18 years or older (Kirchhoff, Lyles et al. 2012, Schneider, Clark et al. 2012). The BRFSS is the largest ongoing public health survey in the world; in 2016, the number of completed interviews was 486,303. The objective of BRFSS is to collect uniform, state-specific data on health risk behaviors, chronic diseases and conditions, access to health care, and use of preventive health services in the United States.

In 2008 the BRFSS began including questions about colonoscopies in even years. Therefore, this study used data from the years 2008, 2010, 2012, 2014, and 2016. Previous studies, using BRFSS from the years 2008, 2010, and 2012, have assessed the effect of cost-sharing reduction on colonoscopies among Medicare beneficiaries following the implementation of the ACA (Hamman and Kapinos 2015). One study used BRFSS to examine trends in breast and CRC screening in the U.S. by race, healthcare coverage, and socio-economic status before the Great Recession (2003-2005), during the recession (2007-2009), and at the beginning of the ACA period (2010-2012) (Wyatt, Pernenkil et al. 2017). Both these studies used a very short time frame beginning with the implementation of the ACA, so the studies may underestimate the effects of policy changes. The sample for this study consists of noninstitutionalized, insured elderly aged 65 to 75 who participated in the survey. For our analyses, only those insured who were in the age group 65 to 75 years were included, bringing the sample size down to 446,981 adults. We excluded individuals with missing values for variables of interest and those who refused to answer questions relevant in creating the main measures for the study. Thus, the analysis sample consisted of 349,899 participants (144,628 men and 205,271 women) aged 65 to 75 years. Figure 1 shows the sample size after exclusion of missing cases.

Main Measures

The outcome of interest in our study is the self-reported receipt of colonoscopies in the previous 10 years. A respondent is considered to have received a colonoscopy if

the individual answered “colonoscopy” to the question, “Was your last test a sigmoidoscopy or colonoscopy?”. To determine the years within which the colonoscopy was received, the responses to the following question was used: “How long has it been since you had your last sigmoidoscopy or colonoscopy?”. We defined our outcome variable as a dichotomous measure of whether an individual was up-to-date with the USPSTF screening recommendation. During our study period, the guideline recommended a colonoscopy be performed once over the previous 10 years.

Based on previous studies (Benarroch-Gampel, Sheffield et al. 2012, Hamman and Kapinos 2015, Cooper, Kou et al. 2016), our analysis included demographic variables (age, sex, race and ethnicity, marital status, and region of residence) as possible covariates explaining adoption of colonoscopy. Age was classified into five categories: 65-66; 67-68; 69-70; 71-72; and 73-75. Sex was classified into two categories: male and female. We incorporated race and ethnicity variable using the following discrete categories: non-Hispanic white, non-Hispanic Black, Hispanic, and other. Marital status was classified into two categories: married and other (divorced, widowed, separated, never married, and unmarried couple). Region of residence was classified into four broad geographic regions of the country based on FIPS codes: Northeast, Midwest, South, and West.

We included two socioeconomic variables in the model as well (household income and educational attainment). Household income was reported using the following income classes: lower than $15,000; $15,000 to $25,000; $25,000 to $35,000; $35,000 to $50,000; and higher than $50,000. Educational attainment was grouped into four

categories: did not graduate high school; graduated high school; attended college; and graduated from college.

We pooled all five cycles of the survey into one large data set. The data set includes individual surveys conducted in the two years prior to the ACA policy change (2008 and 2010) and the three years after (2012, 2014, and 2016). Medicare, the predominant insurance provider among the elderly, waived deductibles for colonoscopies and eliminated coinsurance requirements effective January 1, 2011. To capture the effect of policy change on the receipt of colonoscopies, a policy-shift dummy variable was introduced into the model.

We used geographic availability of gastroenterologists and degree of health awareness of surveyed individuals as possible covariates affecting the receipt of colonoscopies. The American Medical Association (AMA) Health Workforce Mapper reports availability of different specialists by state, and we used the reported number of professionally active gastroenterologists (GI) by state to calculate geographic availability of GIs per 1000 individuals in a given population. We reported the geographic availability of gastroenterologists as a quartile of gastroenterologist availability, meaning we divided the distribution of the variable into four groups having equal frequencies. The hypothesis was that receipt of colonoscopies will be affected by the availability of colonoscopy providers in an area. Previous studies have demonstrated that a greater provider supply has been associated with increased use of colonoscopies (Brouse, Wolf et al. 2008, Haas, Brawarsky et al. 2010, Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017).

BRFSS does not have any direct measure of individual's awareness of colonoscopy as a screening option or the importance assigned by individuals to preventive services which have little or no current benefits but improve future health. One of the concerns in estimating the effect of a policy change over the years is that individuals may become more aware of the importance of colonoscopies as well as other preventive services. Over the years, the awareness level may improve due to ongoing campaigns to popularize the use of colonoscopy as an effective approach in preventing CRC. If we assume that knowledge about all the preventive services are interrelated, "effective" use of one or more of preventive actions will also imply improvements in knowledge about the importance of colonoscopies. We decided to use two proxy measures for this purpose: participation in physical exercise and smoking status. Adoption of physical exercise reflects an individual's willingness to accept a preventive activity to improve health in the future. Since participation in physical exercise represents an individual's willingness to spend resources (time and energy) now for the betterment of health in the future, it may be considered an indirect measure of the degree of importance individuals assign to other preventive services like colonoscopies. Smoking status is a more complex proxy measure, probably reflecting the individual's long-term perspective on future health status and the implicit time discount rate. Smokers are likely to discount future years at a much higher rate than non-smokers and former smokers. Those with lower time preference rate (lower discount rate) are more likely to adopt preventive interventions and screenings (Axon, Bradford et al. 2009, Bradford 2010). We differentiated the individuals in the sample as those who reported physical exercise

within the last 30 days and those who did not. Smoking status was categorized into three groups: current smoker, former smoker, and never smoked.

Statistical Analyses

Descriptive statistics were used to summarize participant characteristics and to report the number and percentage of participants for each of the variables. We also reported the percentage of respondents who had a colonoscopy in the previous 10 years by pre- and post-ACA policy change. We reported the percentage change instead of actual change as the percentage change method more precisely depicts the changes in data over a period of time. Bivariate and multivariate logistic models were used to estimate the effects of the policy-shift on the receipt of colonoscopies among insured elderly aged 65 to 75 years. The multivariate models adjusted the outcome variable for demographic characteristics (age, sex, race/ethnicity, marital status, and region of residence), socioeconomic status (household income and educational attainment), geographic availability of gastroenterologists, health awareness proxies (exercise and smoking status), and the policy change shifter variable. Sampling weights were used to derive national estimates for the sample included in this analysis. All statistical analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC, USA).

RESULTS

The data set had 349,899 adults aged 65 to 75 years (Table 4.1). Non-Hispanic whites were the largest racial and ethnic group (78.7%), followed by Non-Hispanic

blacks (9.2%), Hispanics (7.1%), and other (5.1%). The majority of participants were female (58.7%), married (54.8%), had exercised in the last 30 days (72.7%), and had received a colonoscopy within the last 10 years (67.5%). Figure 4.2 presented the percentage of participants who received a colonoscopy in the last 10 years from 2008 to 2016. During the period from 2008 to 2016, 236,275 participants received a recommended colonoscopy (67.2%). Colonoscopy use increased from 61.2% in 2008 to 69.9% in 2016 ($p<.0001$).

Table 4.2 showed colonoscopy use before and after the implementation of the ACA. Compared with Non-Hispanic blacks, Hispanics, and other participants, Non-Hispanic white participants were more likely to have received a colonoscopy in the last 10 years ($p<.0001$). Compared with individuals living in the South, Midwest, and West regions, individuals living in the Northeast were more likely to receive a recommended colonoscopy ($p<.0001$). Compared with participants who had a household income under $15,000, participants with a household income greater than $50,000 were more likely to receive the recommended colonoscopy ($p<.0001$). We found that the receipt of colonoscopies increased after implementation of the ACA, and that increases were largest among the socioeconomically vulnerable elderly (Table 4.2). Overall, the receipt of colonoscopies increased from 63.5% in pre-ACA years to 69.2% in post-ACA years ($p<.0001$) (Figure 4.3). The receipt of colonoscopies increased by 15.1% among the elderly insured with household incomes under $15,000, but only by 6.5% among those with household incomes greater than $50,000. The receipt of colonoscopies increased by 15.9% among elderly insured who did not graduate high school, but by 7.3% among elderly insured who graduated from college. Rates of colonoscopy use by household

income and individual educational attainment indicated larger gains among the socioeconomically vulnerable elderly (Table 4.2).

Figure 4.4 (a) and (b) showed colonoscopy use before and after the implementation of the ACA by household income and educational attainment. We found that the receipt of colonoscopies increased after the implementation of the ACA for all household income groups, and the increase was the largest among individuals with less than $15,000 household income. In terms of educational attainment, receipt of colonoscopies increased for all groups, but the increases were largest among individuals who did not graduate high school.

Table 4.3 reports the results of the multivariate analysis of factors associated with colonoscopy use over the previous 10 years. Increased use of colonoscopy was associated with older age, being female, exercise status, and smoking status. After controlling for demographic characteristics, socioeconomic status and other relevant variables, the policy shift variable was statistically significant, implying that colonoscopy use increased among the elderly insured after the implementation of the ACA (OR, 1.15; 95% confidence limit [CI], 1.08-1.22), given various socioeconomic, demographic and other relevant covariates. Female participants were 1.19 times more likely to receive a recommended colonoscopy than male participants (OR=1.19, CI, 1.15-1.22). Non-Hispanic blacks were significantly more likely (OR=1.16, CI, 1.10-1.23) and Hispanics were significantly less likely (OR=0.78, CI, 0.72-0.84) to receive recommended colonoscopies, compared with non-Hispanic whites.

We found a strong positive association between being married and the probability of receiving a colonoscopy. Married participants were more likely to receive a

recommended colonoscopy compared to unmarried participants. Individuals living in the highest quartile of gastroenterologist availability states were significantly more likely (OR=1.15, CI, 1.10-1.21) to receive recommended colonoscopies compared with individuals living in the lowest quartile of gastroenterologist availability states. Individuals who had exercised in the past 30 days were 1.23 times more likely to have received a recommended colonoscopy compared with individuals who hadn't exercised in the past 30 days (OR=1.23, CI, 1.19-1.27). Former smokers (OR=1.71, CI, 1.63-1.80) and those who never smoked (OR=1.50, CI, 1.43-1.57) were significantly more likely to have received a recommended colonoscopy compared with current smokers (Table 4.3).

Individuals with a household income greater than $50,000 were 2.10 times more likely to have received a recommended colonoscopy compared with individuals whose household income was less than $15,000 (OR=2.10, CI, 1.97-2.24). Individuals who graduated from college were 1.53 times more likely to have received a recommended colonoscopy compared with individuals who did not graduate high school (OR=1.53, CI, 1.44-1.63). We tested interaction terms combining policy shift variable with race/ethnicity, educational attainment, and household income; but none of the interaction terms were statistically significant. This implies that the effect of race/ethnicity, education, and income on colonoscopy adoption did not change in the post-ACA environment when compared to pre-ACA situation.

DISCUSSION

Analysis of BRFSS data indicates that the receipt of colonoscopies among the elderly insured increased from 63.5% in pre-ACA years to 69.2% in post-ACA years. Elderly insured in the age group 65 to 75 years (most of whom are Medicare beneficiaries) are 1.15 times more likely to be up-to-date with colonoscopy screening after the policy change when compared to their pre-ACA status, after controlling for a number of individual and geographic factors. Although the analysis could not incorporate out-of-pocket expenses directly into the model due to lack of data, it is likely that the increase in colonoscopy uptake observed in the post-ACA years was due to the reduction in cost-sharing. Increased coverage of colonoscopy appears to be more pronounced among elderly insured who are less educated and in lower household income groups.

Consistent with earlier research findings (Hamman and Kapinos 2015), our results confirmed that there was a statistically significant increase in colonoscopy use among elderly beneficiaries aged 65 to 75 years after the implementation of the ACA. The results also correspond with prior literature showing a positive association between cost-sharing reduction and utilization of recommended preventive services (Goodwin and Anderson 2012, Han, Robin Yabroff et al. 2015, Cooper, Kou et al. 2016, Misra, Lloyd et al. 2018). However, even with higher coverage of colonoscopies after ACA implementation, approximately half of the elderly insured in the age group 65-75 years with household income less than $15,000 received a recommended colonoscopy. Moreover, 55.5% of the elderly insured aged 65-75 years without a high school diploma received a colonoscopy in the previous 10 years in post-ACA years. Therefore, even after significant reduction in out-of-pocket expenses for receiving colonoscopies, the coverage

of colonoscopy remains suboptimal and much lower than the 80% target by 2018. It is important to identify specific approaches to encourage socioeconomically disadvantaged elderly to seek colonoscopies in order to achieve a higher rate of progress in achieving the target 80%, even though increases in colonoscopy uptake were the largest among the lower income and education groups in post-ACA levels compared to pre-ACA levels.

Nonetheless, we found a significant increase in colonoscopy use among elderly insured with lower socioeconomic status after implementation of the ACA. This may, in part, reflect the effect of removal of out-of-pocket costs, since financial barriers are found to reduce coverage of cancer screening (Doubeni, Laiyemo et al. 2010), and colonoscopies are expensive (Pyenson, Scammell et al. 2014). It is also possible that the increase in the receipt of colonoscopies among lower socioeconomic groups may reflect the continuation of increasing trends that have been observed nationwide, as well as the proliferation of private health plans (Klabunde, Cronin et al. 2011, Shapiro, Klabunde et al. 2012, Wernli, Hubbard et al. 2014). It is clear that the increase was universal across socioeconomic status and not limited to subjects with lower income and lower levels of education. However, despite the improvements in colonoscopy uptake over the years, the poorest and the most socially disadvantaged groups represent the highest potential for improvement, given their relatively low rates of colonoscopy use. For achieving the target screening rate, additional interventions should be considered in addition to the lowering of barriers to access. The ACA's reduction of financial barriers has improved adherence to CRC screening, but other non-medical costs should be considered more carefully to rapidly improve the screening rates.

There are several barriers to the receipt of colonoscopies other than cost, including perceived loss of utility associated with bowel preparation prior to the test, logistical challenges, not receiving a physician's recommendation for CRC screening, and believing that CRC screening is not important or necessary (McAlearney, Reeves et al. 2005, Guessous, Dash et al. 2010, Jones, Devers et al. 2010). Patients' perception of insurance coverage has been shown to deter cancer screening use (McAlearney, Reeves et al. 2005), which indicates the need for improved awareness of the ACA's cost-sharing reduction provision among the elderly insured population. The Medicare program needs to ensure that all Medicare beneficiaries are aware of the new policy, that part B do not require any deductible or coinsurance for screening colonoscopies. Eliminating the cost-sharing for therapeutic colonoscopies could be the next policy reform to be considered in improving adherence to colorectal cancer screening even further (Hamman and Kapinos 2015).

Previous studies found divergent results of post-ACA changes in CRC screenings among the elderly and Medicare beneficiaries (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Han, Robin Yabroff et al. 2015, Cooper, Kou et al. 2016). Some studies found an increase in the receipt of CRC screening (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015), while others found no change in the use of any cancer screening procedure (Han, Robin Yabroff et al. 2015, Cooper, Kou et al. 2016). Unlike these studies, our study was able to use a longer time-frame to examine the effect of ACA policy changes on colonoscopy use. With this longer time lapse since implementation of the ACA, we found a significant effect of policy change when many other potential factors affecting colonoscopy uptake had been controlled for. We even incorporated the

availability of health care providers in the area as a control factor, something none of the earlier analyses had considered. The supply-side variable indicates that the availability of GIs in the geographic area affects the likelihood of receiving a colonoscopy within the recommended time frame.

This study has several limitations. First, the BRFSS is based on self-reports, which may be subject to recall bias. True screening rates are more likely to be less than 50% for adults aged 50 years or older (Paskett and Khuri 2015). Therefore, one challenge is establishing the accurate rate of colonoscopy receipt. The BRFSS did not carry out cross-checking of reported colonoscopy with individuals' medical records (Ferrante, Ohman-Strickland et al. 2008, Schenck, Klabunde et al. 2008). Second, there is also a possibility of selection bias in this type of survey because less healthy patients may not be included in the sample. Third, the BRFSS does not include information about actual out-of-pocket expenditures or other non-medical expenses associated with the screening, such as opportunity cost associated with time or difficulty in scheduling colonoscopies (Dong, Kalmaz et al. 2011, Petryszyn, Kempinski et al. 2014). Fourth, this study could not distinguish between screening and therapeutic colonoscopies and whether or not the ACA policy itself changed the providers' behavior in terms of recommending screening or therapeutic colonoscopies. Fifth, gastroenterologists are not only providers of colonoscopy and there are regional variations (Benarroch-Gampel, Sheffield et al. 2012, Joseph, Meester et al. 2016). Sixth, there is also the possibility of historical threats to validity (e.g. increasing awareness over time and social norms in support of CRC). Seventh, this study could not assess awareness of CRC. Finally, in 2011 BRFSS changed its weighting methodology through the inclusion of cellular phone respondents. Cellular

phone respondents are likely to be different from others in terms of age and risk of CRC. Therefore, this additional approach of selecting respondents may have affected the sample of 2011 in comparison with samples from the pre-2011 period.

In summary, our results confirmed that there was a statistically significant increase in colonoscopy use among the elderly insured aged 65 to 75 years after the implementation of the ACA. Although Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, individuals are still subject to out-of-pocket medical expenses for therapeutic colonoscopies (Hamman and Kapinos 2015). Our results indicate that the ACA's reduction of financial barriers has improved usage of CRC screening and further improvements will be possible if the costs associated with therapeutic colonoscopies can be reduced or eliminated. Policy makers should also try to understand other related expenses, both medical and non-medical costs, associated with the receipt of colonoscopies by the elderly (Dong, Kalmaz et al. 2011, Petryszyn, Kempinski et al. 2014). Reducing these costs will also help achieve the national target rate of colonoscopy use. Moreover, our results indicate that greater provider supply has been associated with increased use of colonoscopies. An increased supply of providers may have little beneficial effect on race and ethnic disparities in the receipt of colonoscopies or on geographic disparities in the receipt of colonoscopies (Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). Interventions should focus on improving screening in populations living in rural areas and among minorities. A recent study reported that the estimated colonoscopist capacity was sufficient to screen 80% of the eligible U.S. population (Joseph, Meester et al. 2016). However, colonoscopies vary in quality, and high-quality colonoscopies take considerably more

time than that which the average physician spends on such a procedure (Vicari 2010). If a particular area has a short supply of gastroenterologists, short-run alternatives may be possible, such as training primary care providers to conduct colonoscopies (Selby, Cornuz et al. 2016).

The results of this study indicate that the use of colonoscopies increased among the elderly insured after the implementation of the ACA cost-sharing rule for preventive services. Reduction of financial barriers has been effective in improving CRC screening, and further reduction in financial barriers is likely to improve uptake of CRC screening in the future. The financial barriers are not only due to medical care costs but also due to other non-medical expenses, and policy makers should consider how to improve access to preventive services by considering all the potential barriers to access. In general, lowering out-of-pocket expenses for colonoscopies has improved receipt of colonoscopies by all elderly groups; but the increase in coverage was higher for poorer individuals and individuals with low educational attainment. Therefore, reduction in out-of-pocket expenses benefited the disadvantaged elderly population at a higher rate than other elderly groups.

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Table 4.1. Characteristics of Survey Participants Aged 65 to 75 Years: Behavioral Risk Factor Surveillance System (BRFSS), 2008-2016

Characteristic	Total			Pre-ACA (2008, 2010)			Post-ACA (2012, 2014, 2016)		
	N	Weighted N	%	N	Weighted N	%	N	Weighted N	%
Total	**349,899**	**20,760,005**	**100.0**	**125,577**	**7,292,561**	**100.0**	**224,322**	**13,467,444**	**100.0**
Age (years)									
65-66	78,424	4,778,975	23.0	27,686	1,657,607	22.7	50,738	3,121,369	23.2
67-68	72,261	4,293,712	20.7	25,928	1,492,646	20.5	46,333	2,801,066	20.8
69-70	65,746	3,853,545	18.6	22,953	1,308,456	17.9	42,793	2,545,089	18.9
71-72	56,989	3,307,273	15.9	20,739	1,187,668	16.3	36,250	2,119,606	15.7
73-75	76,479	4,526,499	21.8	28,271	1,646,184	22.6	48,208	2,880,315	21.4
Sex									
Male	144,628	10,041,253	48.4	49,856	3,498,723	48.0	94,772	6,542,530	48.6
Female	205,271	10,718,752	51.6	75,721	3,793,838	52.0	129,550	6,924,915	51.4
Race/ethnicity									
Non-Hispanic White	300,176	16,335,132	78.7	107,573	5,787,662	79.4	192,603	10,547,470	78.3
Non-Hispanic Black	23,541	1,900,058	9.2	8,262	625,413	8.6	15,279	1,274,645	9.5
Hispanic	11,393	1,464,786	7.1	4,523	515,157	7.1	6,870	949,629	7.1
Other	14,789	1,060,030	5.1	5,219	364,328	5.0	9,570	695,702	5.2
Married	191,812	13,062,607	62.9	67,832	4,791,316	65.7	123,980	8,271,291	61.4
Region of Residence									
Northeast	63,156	3,721,267	17.9	21,448	1,333,058	18.3	41,708	2,388,209	17.7
Midwest	83,992	4,610,164	22.2	27,263	1,611,787	22.1	56,729	2,998,377	22.3
South	117,730	7,807,516	37.6	45,098	2,740,775	37.6	72,632	5,066,741	37.6
West	85,021	4,621,059	22.3	31,768	1,606,941	22.0	53,253	3,014,117	22.4
Household income									
Less than $15,000	37,975	2,132,736	10.3	16,145	799,267	11.0	21,830	1,333,470	9.9
$15,000 to less than $25,000	71,719	3,999,888	19.3	28,776	1,493,125	20.5	42,943	2,506,764	18.6
$25,000 to less than $35,000	51,045	2,896,727	14.0	20,179	1,105,098	15.2	30,866	1,791,628	13.3

$35,000 to less than $50,000	61,885	3,648,907	17.6	22,442	1,296,287	17.8	39,443	2,352,620	17.5
$50,000 or more	127,275	8,081,747	38.9	38,035	2,598,784	35.6	89,240	5,482,963	40.7
Education									
Did not graduate high school	28,997	2,565,191	12.4	13,251	834,555	11.4	15,746	1,730,636	12.9
Graduated High School	107,851	6,286,535	30.3	43,068	2,350,414	32.2	64,783	3,936,121	29.2
Attended College	92,346	5,878,894	28.3	31,705	1,770,625	24.3	60,641	4,108,269	30.5
Graduated from College	120,705	6,029,384	29.0	37,553	2,336,966	32.0	83,152	3,692,418	27.4
Colonoscopy within 10 years									
No	113,624	6,815,019	32.8	46,619	2,660,497	36.5	67,005	4,154,522	30.8
Yes	236,275	13,944,986	67.2	78,958	4,632,063	63.5	157,317	9,312,922	69.2
Quartile of Gastroenterologist Availability*									
Q1	59,323	1,810,049	8.7	20,757	636,937	8.7	38,566	1,173,112	8.7
Q2	110,334	5,347,096	25.8	39,196	1,864,253	25.6	71,138	3,482,844	25.9
Q3	86,369	7,348,162	35.4	33,101	2,566,325	35.2	53,268	4,781,836	35.5
Q4	93,873	6,254,698	30.1	32,523	2,225,046	30.5	61,350	4,029,653	29.9
Exercise in past 30 days									
No	95,614	5,765,920	27.8	36,007	2,027,556	27.8	59,607	3,738,364	27.8
Yes	254,285	14,994,085	72.2	89,570	5,265,004	72.2	164,715	9,729,081	72.2
Smoking Status									
Current smoker	40,547	2,331,537	11.2	15,127	808,134	11.1	25,420	1,523,403	11.3
Former smoker	149,275	9,133,039	44.0	55,012	3,271,931	44.9	94,263	5,861,108	43.5
Never smoked	160,077	9,295,429	44.8	55,438	3,212,495	44.1	104,639	6,082,934	45.2

Note. *Gastroenterologist availability quartiles are determined by the number of gastroenterologists per 1,000 (2010) in the respondent's state. The American Medical Association (AMA) Health Workforce Mapper reports the availability of different specialists by state, and we have used the reported number of professionally active Gastroenterologists by state to calculate the geographic availability of GIs per 1000 individuals in a given population.

Table 4.2. Colonoscopy Use Before and After Implementation of The Affordable Care Act Policy Change: Behavioral Risk Factor Surveillance System (BRFSS), 2008-2016

Variables	Colonoscopy within the past 10 years		
	Pre ACA	Post ACA	Differences
	%	%	% Change
Total	63.5	69.2	8.9
Age (years)			
65-66	62.2	67.3	8.2
67-68	63.5	69.9	10.0
69-70	64.2	69.8	8.7
71-72	63.8	70.1	9.8
73-75	64.1	69.2	7.9
Sex			
Male	63.7	68.7	7.9
Female	63.4	69.6	9.8
Race/ethnicity			
Non-Hispanic White	65.5	70.9	8.2
Non-Hispanic Black	61.4	70.0	14.0
Hispanic	50.0	56.2	12.5
Other	54.8	59.2	8.1
Married			
Yes	66.7	72.4	8.6
No	57.5	64.0	11.4
Region of Residence			
Northeast	67.3	71.9	6.8
Midwest	64.7	70.2	8.4
South	63.9	70.2	9.8
West	58.5	64.2	9.8
Household income			
Less than $15,000	45.5	52.4	15.1
$15,000 to less than $25,000	55.7	61.1	9.6
$25,000 to less than $35,000	63.4	67.1	5.9
$35,000 to less than $50,000	66.4	71.0	6.9
$50,000 or more	72.1	76.8	6.5
Education			
Did not graduate high school	47.9	55.5	15.9
Graduated High School	61.2	66.8	9.3
Attended College	64.4	71.0	10.3
Graduated from College	70.8	76.0	7.3
Quartile of Gastroenterologist Availability			
Q1	59.5	66.5	11.8
Q2	64.2	70.4	9.6
Q3	61.2	66.9	9.3
Q4	66.7	71.5	7.2
Exercise in past 30 days			
No	57.0	63.0	10.5
Yes	66.0	71.5	8.3
Smoking Status			
Current smoker	49.0	55.7	13.8
Former smoker	66.8	71.8	7.6
Never smoked	63.8	69.9	9.5

Table 4.3. Multivariate Analysis of Factors Associated with Colonoscopy Use: Behavioral Risk Factor Surveillance System (BRFSS), 2008-2016

	Colonoscopy within the past 10 years		
	OR	(95% CI)	
Policy shift	1.15	1.08	1.22
Age (years)			
65-66	1.00		
67-68	1.11	1.06	1.16
69-70	1.15	1.09	1.20
71-72	1.16	1.11	1.22
73-75	1.16	1.11	1.21
Sex			
Male	1.00		
Female	1.19	1.15	1.22
Race/ethnicity			
Non-Hispanic White	1.00		
Non-Hispanic Black	1.16	1.10	1.23
Hispanic	0.78	0.72	0.84
Other	0.70	0.64	0.77
Married			
Yes	1.00		
No	0.84	0.82	0.87
Region of Residence			
Northeast	1.00		
Midwest	0.98	0.92	1.03
South	0.98	0.93	1.03
West	0.74	0.70	0.79
Household income			
Less than $15,000	1.00		
$15,000 to less than $25,000	1.25	1.18	1.33
$25,000 to less than $35,000	1.53	1.44	1.63
$35,000 to less than $50,000	1.69	1.59	1.80
$50,000 or more	2.10	1.97	2.24
Education			
Did not graduate high school	1.00		
Graduated High School	1.24	1.17	1.31
Attended College	1.37	1.29	1.45
Graduated from College	1.53	1.44	1.63
Quartile of Gastroenterologist Availability			
Q1	1.00		
Q2	1.15	1.11	1.19
Q3	1.06	1.02	1.10
Q4	1.15	1.10	1.21
Exercise in past 30 days			
No	1.00		
Yes	1.23	1.19	1.27
Smoking Status			
Current smoker	1.00		
Former smoker	1.71	1.63	1.80
Never smoked	1.50	1.43	1.57
Years	1.03	1.02	1.04

Note: CI= confidence interval; OR= odds ratio.

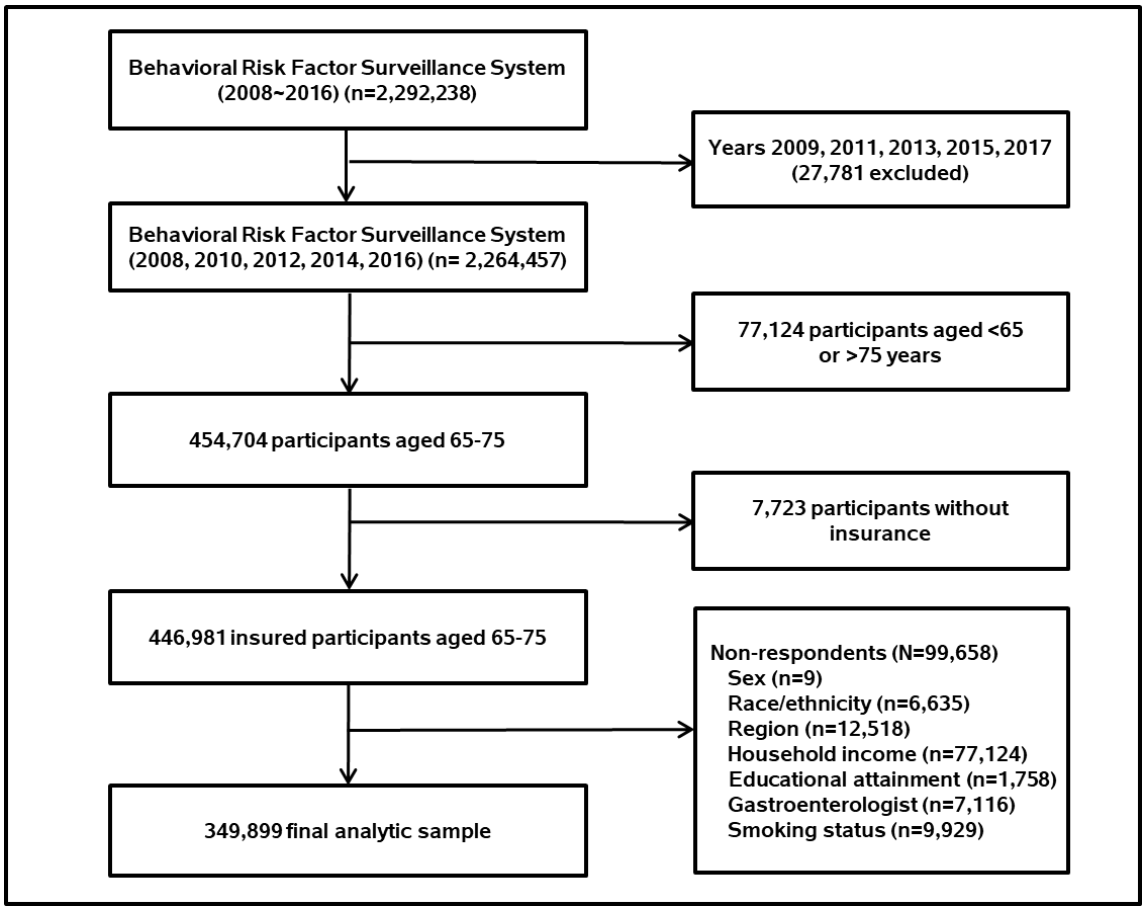

Figure 4.1. BRFSS sample, the exclusion criteria, and the final sample included in the analysis.

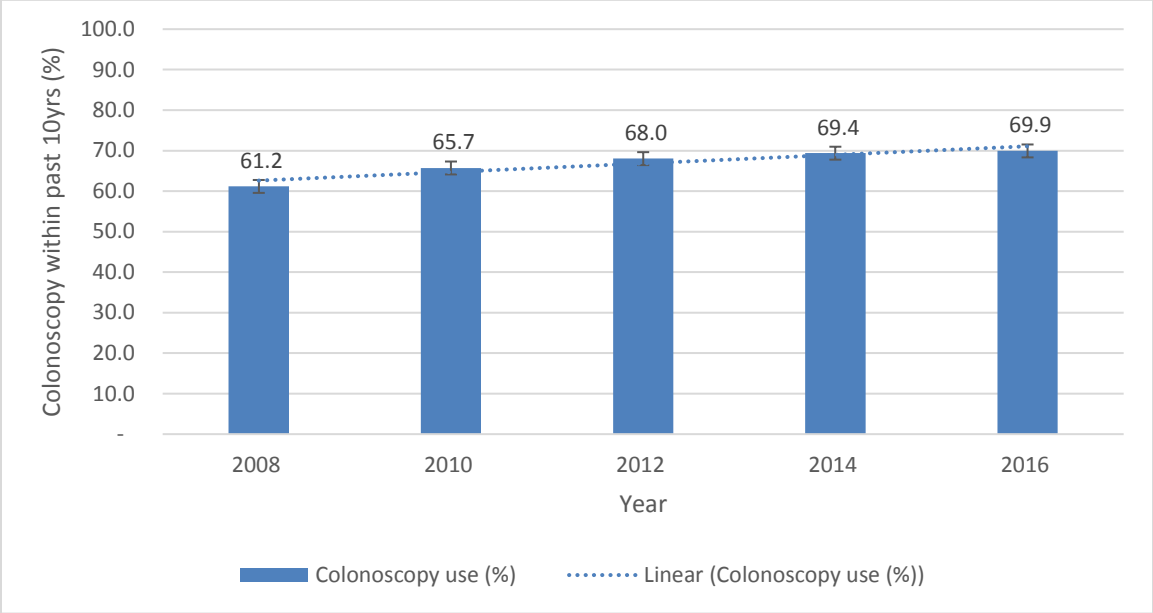

Figure 4.2. Percentage of participants who received a colonoscopy in the previous 10 years from 2008 to 2016

*Statistically significant difference at P<0.05.

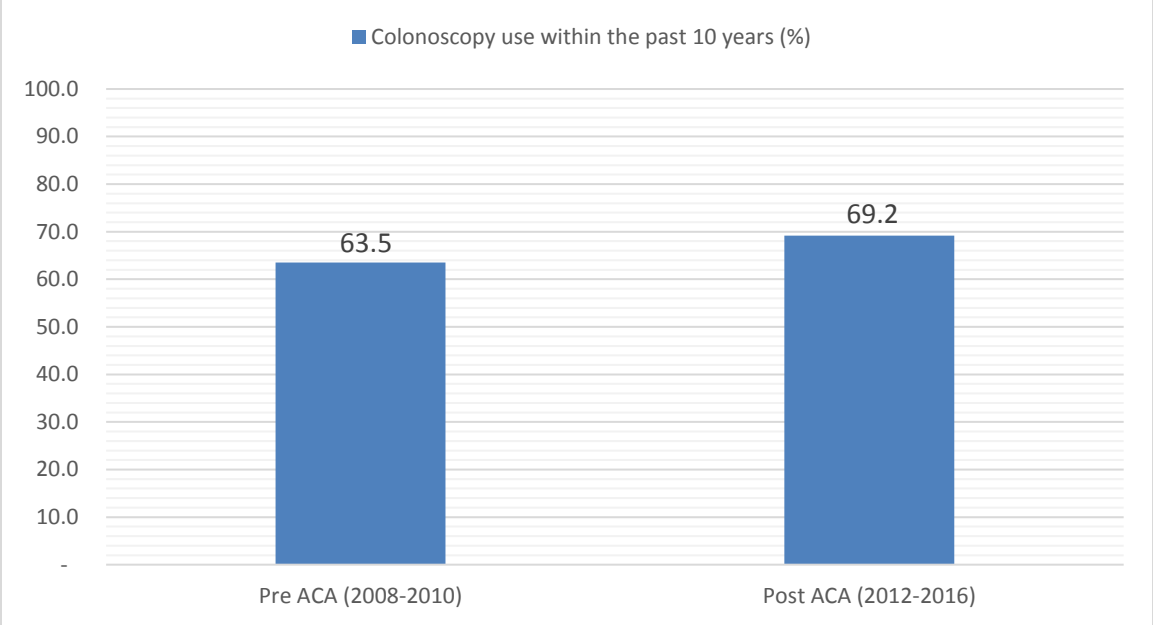

Figure 4.3. Changes in receipt of colonoscopy among insured Elderly aged 65 to 75 years. *Statistically significant difference at P<0.05.

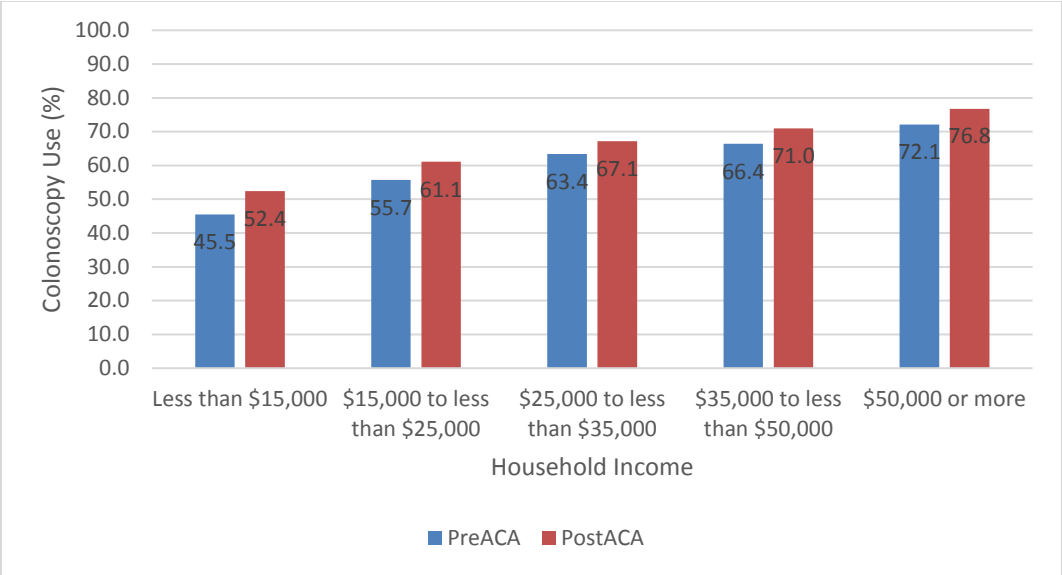

Figure 4.4 (a). Colonoscopy use before and after implementation of the ACA by household income. *Statistically significant difference at P<0.05.

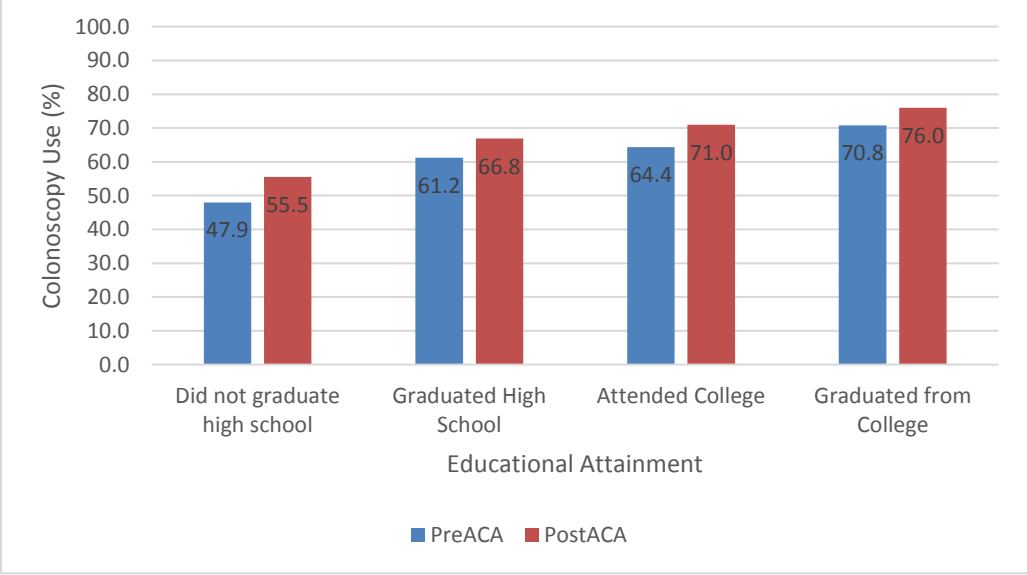

Figure 4.4 (b). Colonoscopy use before and after implementation of the ACA by educational attainment. *Statistically significant difference at P<0.05.

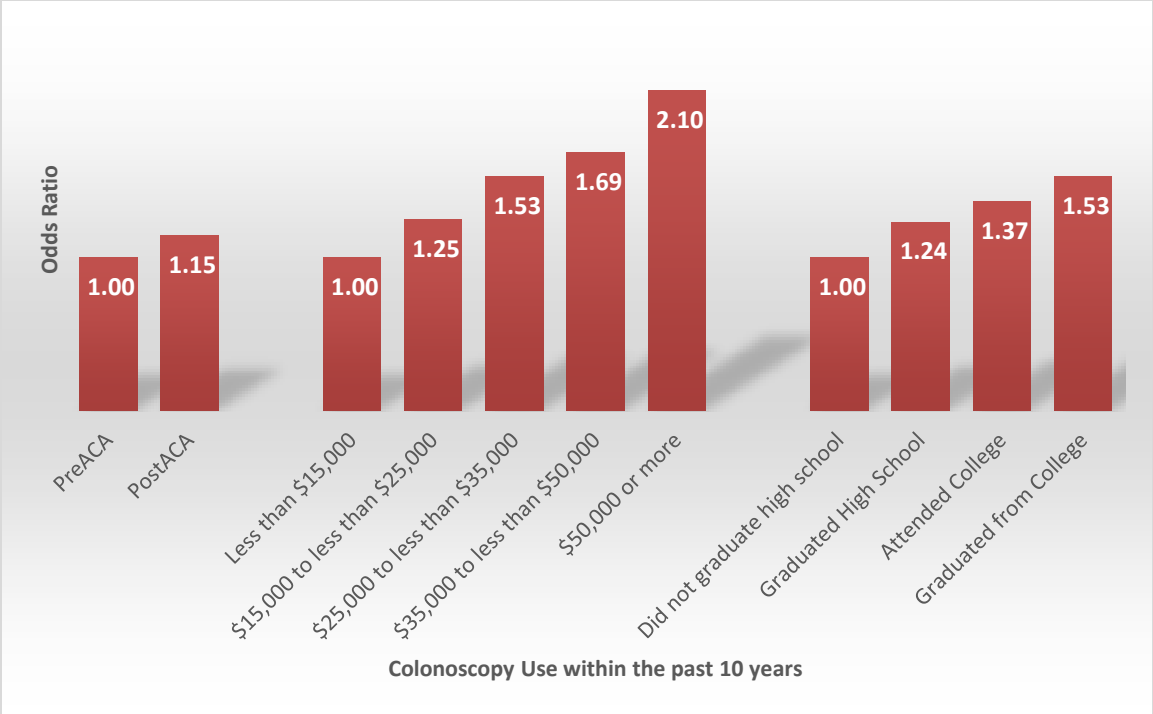

Figure 4.5. Multivariate logistic model for factors associated with colonoscopy use. *Statistically significant.

4.2 Manuscript 2

DECOMPOSING SOCIO-ECONOMIC DISPARITY IN THE USE OF COLONOSCOPY AMONG INSURED ELDERLY POPULATION: COMPARISON OF PRE- AND POST ACA DISPARITY [3]

[3] Lee M. Khan MM. Brant HM. Salloum RG. Chen BK. Decomposing Socio-economic Disparity in the use of Colonoscopy among Insured Elderly Population: Comparison of Pre- and Post-ACA Disparity. Preparing in *Med Care.*

Abstract

Background: Increases in CRC screening rates have been demonstrably effective in reducing the incidence of and mortality from this disease, but the use of CRC screening remains lower than the use of preventive interventions for other screening-amenable cancers; and CRC screening rates are below the 80% NCCRT target coverage and the 70% HP2020 target coverage.

Objective: The objectives of this paper are to examine how income-related disparities in CRC screening in the United States have changed over the past decade, especially in the years prior to and after the implementation of Affordable Care Act (ACA) and to quantify the contributions of different factors in explaining the disparity in the use of colonoscopies among elderly population with health insurance coverage.

Methods: Five cycles (2008, 2010, 2012, 2014, and 2016) of Behavioral Risk Factor Surveillance System (BRFSS) data were utilized. To examine income-related disparities in the use of CRC, individuals aged 65 to 75 were included, and the Concentration Index (CI) was calculated before and after the implementation of ACA. To identify and quantify the contribution of different factor, a decomposition analysis of CI was conducted.

Results: CIs decreased from 0.1935 in pre-ACA years to 0.1813 in the post-ACA years among the elderly, indicating that the disparity in the use of colonoscopy was relatively low and the disparity index declined after the implementation of ACA. Decomposition analyses showed that whereas decreases in disparities derived largely from income and

educational level, higher level of income and educational attainment were major contributors to the observed disparities in colonoscopy use.

Conclusions: Our findings indicate that the ACA's removal of financial barriers may have contributed towards the reduction in disparity of colonoscopy use. It appears that financial aspects will not be adequate for further reduction in disparity. More direct interventions, e.g., improved knowledge, better access and lower indirect cost will be helpful in improving screening among low income and low educational attainment households.

Keywords: Colonoscopy, Disparity, Concentration Index, Decomposition

Introduction

The incidence of and mortality rates from colorectal cancer (CRC) have been steadily decreasing in the United States (US) since the 1980s (Weir, Thompson et al. 2015, Siegel, Miller et al. 2017). This may, in part, be due to substantial advances in screening, a general agreement among health care providers and policy-makers in screening recommendations and evidence of cost-effectiveness of screening (Cunningham, Atkin et al. 2010, Edwards, Ward et al. 2010, Lieberman 2010, US Preventive Services Task Force 2016, Martin, Tully et al. 2017, Partin, Gravely et al. 2017). Increases in screening have been demonstrably effective in reducing the incidence of and mortality from this disease, and they explain about half of the observed decrease in

these rates (Whitlock, Lin et al. 2008, Edwards, Ward et al. 2010, Siegel, Miller et al. 2017).

The U.S. Preventive Services Task Force (USPSTF) strongly recommends that for individuals at average risk, CRC screening should begin at age 50 and continue until age 75. The recommendation is guided by the evidence that screening for CRC generates substantial net benefits for the target group (Whitlock, Lin et al. 2008, Koretz 2016, US Preventive Services Task Force 2016). The USPSTF recommends screening by any of the accepted methods, as any sort of screening test is better than no screening at all (Atkin, Edwards et al. 2010, Quintero, Castells et al. 2012, Patel and Kilgore 2015). Not all screening options, however, are equally attractive to all individuals; depending upon individuals' health history and preferences, the choices may vary significantly. From a clinical perspective, colonoscopy is the most preferred method, because an effective colonoscopy allows doctors to examine the entire length of the colon and to remove all cancers and precancerous polyps, if found, in the same procedure (Levin, Lieberman et al. 2008, Rex, Johnson et al. 2009, Wolf, Basch et al. 2016). Colonoscopy is also recommended as a follow-up when another CRC screening is positive. Moreover, colonoscopy has been validated in a randomized trial as providing a clear mortality reduction benefit (Zauber, Winawer et al. 2012, Patel and Kilgore 2015, Koretz 2016, US Preventive Services Task Force 2016).

Nonetheless, the self-reported CRC screening rate in the 2013 National Health Interview Survey was only 58%, and the National Committee for Quality Assurance (NCQA) indicates that 60% of commercial insurance buyers and 68.5% of Medicare plan members received an appropriate CRC screening in 2016 (Paskett and Khuri 2015). The

Behavioral Risk Factor Surveillance System (BRFSS) data indicate that around 65% of adults aged 50 to 75 have undergone one of the colorectal screening tests recommended by USPSTF, and around 60% of adults aged 50 to 75 have received a colonoscopy within the past 10 years (Joseph, King et al. 2012).

Previous studies have identified the determinants of CRC screening disparities, and the majority of studies have found that individual socioeconomic status (SES) is an important determinant (Courtney, Paul et al. 2013, Fedewa, Ma et al. 2015, Meyer, Allard et al. 2016, White, Thompson et al. 2017). Growing evidence indicates that screening colonoscopy is most likely among individuals with higher income, even among insured population (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Solbak, Xu et al. 2018). Healthy People 2020 (HP2020) has four overarching goals: to attain high-quality, longer lives free of preventable disease, to create social and physical environments, to promote quality of life, healthy development, and healthy behaviors, and to eliminate disparities (White, Thompson et al. 2017). Understanding the temporal trends in disparities as well as the factors explaining the disparities are important in formulating policy options to reduce disparity in the use of screening tests like colonoscopy (White, Thompson et al. 2017). To increase CRC screening rates and reduce the disparities in screening, beginning January 1, 2011, Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies (Howard, Guy et al. 2014, Hamman and Kapinos 2015). Individuals with other type of insurance coverage also saw their out-of-pocket costs decline after the implementation of ACA.

From a policy perspective, identifying the factors or characteristics that contribute most to the observed disparities in colonoscopy is important in designing effective programs and prioritizing interventions. Decomposing income-related disparities in colonoscopy use can help uncover factors that are potentially modifiable. Therefore, the purpose of this study is to examine changes in income-related disparities in colonoscopy use in pre-ACA and post-ACA years and to decompose the disparities into important constituent factors.

METHODS

Data

This study used 2008-2016 BRFSS data, an annual, nationally representative survey implemented in the United States, the District of Columbia, Puerto Rico, Guam, the US Virgin Islands, American Samoa, and Palau. BRFSS uses random-digit telephone dialing methods to sample noninstitutionalized adults aged 18 years or older (Kirchhoff, Lyles et al. 2012, Schneider, Clark et al. 2012). The BRFSS is the largest ongoing public health survey in the world; in 2016, the number of completed interviews was 486,303. The objective of BRFSS is to collect uniform, state-specific data on health risk behaviors, chronic diseases and conditions, access to health care, and use of preventive health services in the United States.

In 2008 the BRFSS began including questions about colonoscopies in even years. Therefore, this study used data from the years 2008, 2010, 2012, 2014, and 2016. Previous studies, using BRFSS from the years 2008, 2010, and 2012, have assessed the effect of cost-sharing reduction on colonoscopies among Medicare beneficiaries following the implementation of the ACA (Hamman and Kapinos 2015). One study used BRFSS to examine trends in breast and CRC screening in the U.S. by race, healthcare coverage, and socio-economic status before the Great Recession (2003-2005), during the recession (2007-2009), and at the beginning of the ACA period (2010-2012) (Wyatt, Pernenkil et al. 2017). These studies used a very short time frame beginning with the implementation of the ACA, so the studies may underestimate the effects of policy changes. The sample for this study consists of noninstitutionalized, insured elderly aged 65 to 75 who participated in the survey from the years 2008, 2010, 2012, 2014, and 2016. For our analyses, only those insured who were in the age group 65 to 75 years were included, bringing the sample size down to 446,981 adults. We excluded individuals with missing values for variables of interest and those who refused to answer questions relevant in creating the main measures for the study. Thus, the analysis sample consisted of 349,899 participants (144,628 men and 205,271 women) aged 65 to 75 years.

Definition of the Measures Used

The variable of interest for the study is the self-reported receipt of a colonoscopy in the previous 10 years. A respondent is considered to have received a colonoscopy if the individual answered “colonoscopy” to the question, “was your last test a

sigmoidoscopy or colonoscopy?". To determine the years within which the colonoscopy was received, the responses to the follow-up question were used: "how long has it been since you had your last sigmoidoscopy or colonoscopy?". We defined our outcome variable as a dichotomous measure of whether an individual was up-to-date with the USPSTF screening recommendation. During our study period, the guidelines recommended having a colonoscopy once every 10 years.

The literature has identified several sets of variables to explain variations in colonoscopy use (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Courtney, Paul et al. 2013, Howard, Guy et al. 2014, Ramdass, Petraro et al. 2014, Hamman and Kapinos 2015, Partin, Gravely et al. 2016, Grzywacz, Hussain et al. 2017). We included age, sex, race and ethnicity. Age was categorized into five groups: 65-66, 67-68, 69-70, 71-72, and 73-75. Sex was classified into two categories: male and female. Participants' race and ethnicity was categorized into four groups: non-Hispanic white, non-Hispanic Black, Hispanic, and other. We dichotomized marital status as married or not married. We described geographic characteristics by census region (Northeast, Midwest, South, and West). Based on previous studies (Benarroch-Gampel, Sheffield et al. 2012, Hamman and Kapinos 2015, Solmi, Von Wagner et al. 2015, Cooper, Kou et al. 2016), our analysis included household income and educational attainment. We used a categorical measure of annual household income with the following categories: lower than $10,000; $10,000 to $14,999; $15,000 to $19,999; $20,000 to $24,999; $25,000 to $34,999; $35,000 to $49,999; $50,000 to $74,999; and $75,000 or more. Educational attainment was classified into four categories: did not graduate high school; graduated high school; attended college; and graduated

from college. Racial and ethnic disparities in CRC screening had already been broadly documented, and most studies found that individuals belonging to ethnic minorities were less likely to adhere to screening guidelines; lower socio-economic status (indicating dimensions such as income, education, and employment status) among ethnic minority groups is considered the most likely explanation for this finding (Shih, Zhao et al. 2006, Benarroch-Gampel, Sheffield et al. 2012, Burnett-Hartman, Mehta et al. 2016, Hong, Tauscher et al. 2017). In addition, lower educational attainment is associated with lower adherence to CRC screening guidelines (Gimeno Garcia 2012, Kobayashi, Wardle et al. 2014).

The final data set generated for this analysis includes two years of information prior to the implementation of ACA (2008 and 2010) and three years of information following the implementation of ACA (2012, 2014, and 2016). Since a large majority of this group is covered by Medicare, the policy changes adopted by Medicare should have significant impact on the use of colonoscopy. For controlling the time trade-off rates of individuals and willingness to spend resources for improving future health status, we incorporated two variables in the analysis: whether the individual exercised or not within previous 30 days and whether the individual is a current smoker, former smoker, or never smoked.

Concentration index

The concentration index has demonstrated its usefulness as a tool in measuring health sector disparities. The concentration index measures the degree of disparity in the

utilization of various medical care services or outcomes. To estimate the concentration index, one variable must be used as the main metric to rank households on the basis of levels of living or socioeconomic status. We can use household income as the measure to calculate the concentration index in the use of colonoscopies. The standard concentration index (CI), denoted below by CI, can be written as follows:

$$CI = \frac{2}{n\mu}\sum_{i=1}^{n} y_i\, R_i \; - 1$$

where n is the sample size, y_i is healthcare utilization of individual i, μ is its mean and $R_i = \frac{i}{N}$ is the fractional rank of individual i in household income distribution. For a given $\mu > 0$, the maximum of the concentration index is when the poorest i individuals have a value of y_i equal to zero and the richest $n - \ i$ individuals have a value of y_i equal to 1. In this case, the value of CI will be maximum at +1[4]. If the poorest person uses CRC screening and not anyone else, the CI will have the value of -1. If the richest person uses CRC screening and not anyone else, the CI will have the value of +1. If CI equals zero, then there is no income-related disparity in the distribution of CRC screening. As this analysis have used a binary response indicating whether or not a insured elderly had a recommended colonoscopy, normalized concentration index employing the Wagstaff decomposition method was applied (Wagstaff 2005). Standard

[4] $CI = \frac{2}{n\mu}\sum_{i=1}^{n} y_i\, R_i \; - 1 = \frac{2}{(n-1)\mu}\sum_{i=1}^{n-1} y_i(=0)\, R_i \; - 1 + \frac{2}{(1)\mu}\sum_{i=n-1}^{n} y_i(=1)\, R_i \; = 0 - 1 + 2 = +1$

errors for the normalized index correct for both autocorrelation and heteroscedasticity (Cai, Coyte et al. 2017).

$$CI_n = \frac{CI}{1 - \mu}$$

Decomposition Analyses

We first compared the difference in concentration index between the pre- and post-ACA periods. Decomposition analysis of the concentration index was used to determine the impact of a range of sociodemographic variables on the disparity in colonoscopy use. Decomposition analysis is based on partitioning of total disparity into the precise disparities observed by each individual factor (van Doorslaer, Koolman et al. 2004). A logistic regression is applied with a linear estimation to allow for the correct decomposition. The following equation shows the linear estimation of the logistic results where β_k^n are the average partial effects of each variable (x) – yielding the likelihood of a screening colonoscopy (y).

$$y_i = \sum_k \beta_k^n x_i^k + \varepsilon_i$$

The following equation shows the decomposition analysis comprised of average partial effects of each x as well as their means and individuals concentration index. In this equation, the first expression shows the contribution of equivalized income, the second expression shows effects of other socio-demographic variables perceived to influence colonoscopy usage, and the final expression refers to the residual term.

$$\overline{CI}_n = \left(\frac{\beta_k \overline{x}_r}{\mu}\right) \overline{CI}_r \sum_k \left(\beta_k \frac{\overline{x}_k}{\mu}\right) \overline{CI}_k + \frac{GC_\varepsilon}{\mu}$$

We presented CIs prior to the ACA policy change (2008 and 2010) and after ACA implementation (2012, 2014, and 2016). We identified the largest determinant of disparity observed in pre-ACA years and post ACA years. Positive values of the overall CIs suggest that colonoscopy use was concentrated among individuals with higher household incomes. CIs were broken down by confounder and represented as contributions to the overall income-related disparity in the use of colonoscopies with percentage contributions in brackets. The percentage contribution is attained by dividing the absolute contribution by the overall income-related disparity. We included age, sex, race and ethnicity, marital status, household income, educational attainment, region of residence, exercise, and smoking status as possible determinants.

RESULTS

Table 1 shows the descriptive statistics for pre-ACA years and post-ACA years in the total sample. The data set had 349,899 respondents aged 65 to 75. The majority of participants were female (59%), married (55%), exercised in the past 30 days (73%), and had a colonoscopy in the past 10 years (68%). The receipt of colonoscopy increased from 63% in pre-ACA years to 70% in post-ACA years (Table 1).

Table 2 presents the descriptive characteristics of the respondents by colonoscopy use among insured elderly. Among the 349,899 insured elderly aged 65 to 75 years, 236,275 (67%) indicated that they had received colonoscopies in the previous 10 years. The receipt of colonoscopy was highest among those aged 69-70 (68%). The receipt of colonoscopy was more prevalent among high income than those with low incomes (77% vs. 46%; p <.0001). About 74% of those graduated from college had colonoscopies compared to 53% of those who did not graduate from high school (74% vs. 53%; p <.0001). The receipt of colonoscopy was slightly higher among the respondents who exercised in the past 30 days than those who did not (70% vs. 61%; p <.0001). In addition, colonoscopy was more prevalent among former smokers or those never smoked than the current smokers (70% and 68% vs. 53%; p<.0001).

Table 3 presents the decomposition of CIs in the use of colonoscopy in pre-ACA and post-ACA years. Elasticity values in the first column shows the sensitivity of colonoscopy use for each of the factors. The CI for each factor is presented in the second column, which shows the distribution of each factor by income levels. It tests the levels of influence for each factor according to income level. From pre-ACA to post-ACA years, overall CIs decreased from 0.1935 to 0.1813. Positive values of the overall CIs suggest that colonoscopy use was more concentrated among individuals with higher household incomes. For example, a positive value for educational attainment (education – attended college or graduated from college) in Table 3 indicates that educational attainment has a pro-rich distribution. Lastly, the final two columns of Table 3 present, respectively, the absolute and percentage contributions to overall income-related disparity in the use of colonoscopies. The absolute contribution is the product of the elasticity and

the partial concentration index for each of the factors, so it depends both on the impact of each variable on the use of colonoscopy, and on its unequal distribution by household income. The positive absolute contribution of a factor indicates that the factor contributes to the measured pro-rich disparities in the use of colonoscopies. The percentage contribution can be obtained by dividing the absolute contribution by the overall income-related disparity. The highest income group was consistently the largest contributor to disparity in the use of colonoscopies in both pre-ACA (54%) and in post-ACA years (79%). The highest income and highest educational attainment were the major contributors to the existing disparity in the use of colonoscopies. Having a college degree contributed approximately 31% to the observed CI for the use of colonoscopies in pre-ACA years and 21% to CI in post-ACA years. Physical exercise in the previous 30 days and being a non-smoker positively contributed to colonoscopy disparity in both the pre-ACA and post-ACA years.

The concentration indices (CIs) for colonoscopy use in Figure 2 highlight the income-related. The positive values of the CI observed suggest that colonoscopy use has been more prevalent among the higher income individuals and the CI value has declined slightly from 0.1935 in pre-ACA years to 0.1813 in post-ACA years (Table 3).

DISCUSSION

The aim of this study was to compare changes in income-related disparities in colonoscopy use between pre-ACA and post-ACA years and to identify the contributors

that affect the income-related disparities. Our concentration indices imply that significant income-related disparity in the use of colonoscopies exists among elderly insured individuals in the age group 65 to 75, and that disparities in the use of colonoscopy lessened after the implementation of ACA. A plausible explanation for the observed decline in disparities may be due to the reduction in cost-sharing. The results are consistent with the findings of an earlier study which found that the expansions in the coverage of CRC screening are associated with reductions in disparities (Hamman and Kapinos 2015).

We found that income and educational attainment were the major contributors of disparity in the use of colonoscopies. Decomposition analysis show that the highest income group was consistently the largest contributor to disparity in pre-ACA (54%) and post-ACA years (79%) and having a college degree contributed approximately 31% to the observed disparities in pre-ACA years and 21% in post-ACA years. The previous study that identified income and educational attainment as the most important factors affecting observed disparity among insured population aged 50 to 64 years indicates that lower income and educational attainment together accounted for 59% of the explained disparity (Hamman and Kapinos 2015). Consistent with our study, a previous study examining the cervical cancer screening across 67 countries showed that income and educational attainment are the key determinants of disparities in uptake despite the existence of national policy assuring equal access to preventive services (McKinnon, Harper et al. 2011). Since income is such a significant contributor, policy makers should focus on strategies to identify how to improve access to screening services by poorer sections of the population. Reducing the financial barriers further may help but it is also

possible that accessing services, especially preventive services, involves higher opportunity cost for the poorer individuals than for richer individuals. In the short-run, eliminating the remaining difference in cost-sharing between screening and therapeutic colonoscopies could be an approach for reducing disparities in the use of colonoscopies among Medicare beneficiaries (Hamman and Kapinos 2015).

In this analysis, we found that colonoscopy use has remained pro-rich even after the introduction of ACA (CIs: 0.1935 in pre-ACA years to 0.1813 in post-ACA years). Our literature review did not find similar studies in the USA although few international studies can be used for comparing our results (Burns, Walsh et al. 2012, Walsh, Silles et al. 2012, Carrieri and Wuebker 2013, Kim and Hwang 2016). To better understand how the values of CIs in this study differ from other studies, we compared the CI values with available international studies. A number of studies found pro-rich disparities in CRC screening uptake in England (CI: 0.164), Ireland (CI: 0.070), and Korea (CI: 0.131) although the CI values are lower than what was obtained for the US elderly population. In addition, some studies reported pro-rich disparities in prostate cancer screenings in Ireland (CIs: 0.169 in the 40-54 age group, 0.157 in the 55-69 age group, 0.230 in the 70 and over age group), gastric cancer screening (CI: 0.132) in Korea, mammography use (CI:0.144) in France, and mammography use (CI:0.125) in Germany. Again, the CI values are smaller than what we found in our empirical analysis. Lower disparity in countries with national health insurance programs is expected but the existence of disparity even in these countries point to the importance of examining other factors associated with socioeconomics that directly or indirectly lower access to preventive services. To identify how the USA can further improve the uptake of colonoscopies, it

will be useful to analyze the proximate factors that have allowed other countries to achieve much lower disparity. Disparity in the use of colonoscopies still persists in the USA after the implementation of ACA in the US implying that coverage of screening programs by health insurance is one of the important steps towards reducing disparity but insurance coverage alone will not be sufficient to reduce the disparity by a significant extent. One plausible explanation is that cancer screening uptake may be influenced by other factors that are correlated with income. For instance, low income individuals may have lower physical access due to distance or face greater restrictions in their work to leave income earning activities for one full day. The loss of income due to absences from work may also be higher for the poorer groups as they are more likely to be employed on hourly basis. One study assessed the patterns and reasons for missed work related to colonoscopies and found that 34% of working individuals missed work for more than one day when they had their screenings scheduled on a Tuesday, Wednesday, or Thursday. This study also found that 32% took the previous day off as well mainly for the need for bowel preparation, 10% took the day after off, primarily as a precautionary measure after sedation rather than in response symptoms, and 9% took both days off. Moreover, colonoscopy procedures require a significant amount of time investment from friends and family members. 45% of individuals had friends or family members who also took time off work for the procedure (Dong, Kalmaz et al. 2011). These costs, to some extent, can be diminished through patient education on the procedure, and by scheduling colonoscopies on Mondays and Fridays (Dong, Kalmaz et al. 2011).

Compared to traditional regression analysis, CI has its strengths and limitations. One strength is that because all respondents were included in the calculation of CI, results

are not likely to be biased by the small sample sizes present in some subgroups. Another strength is that CI is especially sensitive to changes in socio-economic distribution. The primary limitation of CI is that it can only be applied when a strict ranking of households is available using a valid measure of socioeconomic status.

Despite these limitations, this study provides evidence of changes in income-related disparities in colonoscopy use among insured elderly from pre-ACA years to post-ACA years. Our findings indicate that the ACA's removal of financial barriers may have contributed towards observed decrease in the disparity of colonoscopy use. Interventions aimed at reducing disparities should focus on improving screening in populations with relatively low income and education. Further studies are needed to identify the barriers that prevent low-income and low-educational attainment individuals from seeking colonoscopy despite Medicare's waiver of Part B deductibles for all colonoscopies and elimination of coinsurance for screening colonoscopies.

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Table 4.4 Characteristics of Survey Participants Aged 65 to 75 Years: Behavioral Risk Factor Surveillance System (BRFSS), 2008-2016

	Total		Pre-ACA		Post ACA	
Characteristic	**N**	**Weighted %**	**N**	**Weighted %**	**N**	**Weighted %**
Total	349,899	100.0	125,577	100.0	224,322	100.0
Age (years)						
65-66	78,424	23.0	27,686	22.7	50,738	23.2
67-68	72,261	20.7	25,928	20.5	46,333	20.8
69-70	65,746	18.6	22,953	17.9	42,793	18.9
71-72	56,989	15.9	20,739	16.3	36,250	15.7
73-75	76,479	21.8	28,271	22.6	48,208	21.4
Sex						
Male	144,628	48.4	49,856	48.0	94,772	48.6
Female	205,271	51.6	75,721	52.0	129,550	51.4
Race/ethnicity						
Non-Hispanic White	300,176	78.7	107,573	79.4	192,603	78.3
Non-Hispanic Black	23,541	9.2	8,262	8.6	15,279	9.5
Hispanic	11,393	7.1	4,523	7.1	6,870	7.1
Other	14,789	5.1	5,219	5.0	9,570	5.2
Married	191,812	62.9	67,832	65.7	123,980	61.4
Region of Residence						
Northeast	63,156	17.9	21,448	18.3	41,708	17.7
Midwest	83,992	22.2	27,263	22.1	56,729	22.3
South	117,730	37.6	45,098	37.6	72,632	37.6
West	85,021	22.3	31,768	22.0	53,253	22.4
Household income						
Less than $10,000	14,258	4.1	6,171	4.6	8,087	3.9
$10,000 to less than $15,000	23,717	6.1	9,974	6.4	13,743	6.0
$15,000 to less than $20,000	30,639	8.3	12,442	8.8	18,197	8.1
$20,000 to less than $25,000	41,080	10.9	16,334	11.7	24,746	10.5
$25,000 to less than $35,000	51,045	14.0	20,179	15.2	30,866	13.3
$35,000 to less than $50,000	61,885	17.6	22,442	17.8	39,443	17.5
$50,000 to less than $75,000	55,472	16.5	17,758	15.6	37,714	16.9
$70,000 or more	71,803	22.5	20,277	20.0	51,526	23.8
Education						
Did not graduate high school	28,997	12.4	13,251	11.4	15,746	12.9
Graduated High School	107,851	30.3	43,068	32.2	64,783	29.2
Attended College	92,346	28.3	31,705	24.3	60,641	30.5
Graduated from College	120,705	29.0	37,553	32.0	83,152	27.4
Colonoscopy within 10 years						
Yes	236,275	67.2	78,958	63.5	157,317	69.2
No	113,624	32.8	46,619	36.5	67,005	30.8
Exercise in past 30 days						
Yes	254,285	72.2	89,570	72.2	164,715	72.2
No	95,614	27.8	36,007	27.8	59,607	27.8
Smoking Status						
Current smoker	40,547	11.2	15,127	11.1	25,420	11.3
Former smoker	149,275	44.0	55,012	44.9	94,263	43.5
Never smoked	160,077	44.8	55,438	44.1	104,639	45.2

Table 4.5 Descriptive characteristics of the respondents by colonoscopy use among insured elderly aged 65 to 75 Years, 2008-2016

Variables	Total		Colonoscopy Uptake				P-value
			Yes		No		
	N	%	N	%	N	%	
Age (years)							
65-66	78,424	22.4	52,092	65.5	26,332	34.5	<.0001
67-68	72,261	20.7	49,065	67.7	23,196	32.3	
69-70	65,746	18.8	44,776	67.9	20,970	32.1	
71-72	56,989	16.3	38,826	67.8	18,163	32.2	
73-75	76,479	21.9	51,516	67.3	24,963	32.7	
Sex							
Male	144,628	41.3	97,734	67.0	46,894	33.0	0.2031
Female	205,271	58.7	138,541	67.4	66,730	32.6	
Race/ethnicity							
Non-Hispanic White	300,176	85.8	205,396	69.0	94,780	31.0	<.0001
Non-Hispanic Black	23,541	6.7	15,638	67.2	7,903	32.8	
Hispanic	11,393	3.3	6,539	54.0	4,854	46.0	
Other	14,789	4.2	8,702	57.7	6,087	42.3	
Married	191,812	54.8	137,617	70.3	54,195	29.7	<.0001
Region of Residence							
Northeast	63,156	18.1	44,832	70.2	18,324	29.8	<.0001
Midwest	83,992	24.0	56,513	68.3	27,479	31.7	
South	117,730	33.7	79,992	68.0	37,738	32.0	
West	85,021	24.3	54,938	62.2	30,083	37.8	
Household income							
Less than $10,000	14,258	4.1	7,015	46.0	7,243	54.0	<.0001
$10,000 to less than $15,000	23,717	6.8	12,602	52.4	11,115	47.6	
$15,000 to less than $20,000	30,639	8.8	17,438	56.0	13,201	44.0	
$20,000 to less than $25,000	41,080	11.7	25,215	61.5	15,865	38.5	
$25,000 to less than $35,000	51,045	14.6	33,674	65.7	17,371	34.3	
$35,000 to less than $50,000	61,885	17.7	43,352	69.4	18,533	30.6	
$50,000 to less than $75,000	55,472	15.9	41,231	73.6	14,241	26.4	
$70,000 or more	71,803	20.5	55,748	76.5	16,055	23.5	
Education							
Did not graduate high school	28,997	8.3	15,109	53.1	13,888	46.9	<.0001
Graduated High School	107,851	30.8	68,862	64.7	38,989	35.3	
Attended College	92,346	26.4	62,647	69.0	29,699	31.0	
Graduated from College	120,705	34.5	89,657	74.0	31,048	26.0	
Exercise in past 30 days							
No	95,614	27.3	58,488	60.9	37,126	39.1	<.0001
Yes	254,285	72.7	177,787	69.6	76,498	30.4	
Smoking Status							
Current smoker	40,547	11.6	21,566	53.4	18,981	46.6	<.0001
Former smoker	149,275	42.7	104,426	70.0	44,849	30.0	
Never smoked	160,077	45.8	110,283	67.8	49,794	32.2	
Total	349,899	100.0	236,275	67.2	113,624	32.8	

Table 4.6 Decomposition Analysis of participation of colonoscopy among Insured Elderly: BRFSS, 2008-16

Variables	Pre ACA (2008, 2010)				Post ACA (2012, 2014, 2016)			
	Elasticity	CI	Contr.	% contr.	Elasticity	CI	Contr.	% contr.
Age (years)								
65-66	1.000				1.000			
67-68	0.003	0.045	0.001	0.288	0.006	0.027	0.001	0.326
69-70	0.005	-0.004	0.000	-0.046	0.006	0.000	0.000	-0.005
71-72	0.005	-0.027	-0.001	-0.251	0.005	-0.013	0.000	-0.143
73-75	0.008	-0.085	-0.003	-1.427	0.006	-0.063	-0.002	-0.871
Sex								
Male	1.000				1.000			
Female	0.054	-0.200	-0.043	-22.279	0.055	-0.161	-0.036	-19.638
Race/ethnicity								
Non-Hispanic White	1.000				1.000			
Non-Hispanic Black	0.002	-0.088	-0.001	-0.266	0.004	-0.088	-0.002	-0.823
Hispanic	-0.004	-0.097	0.002	0.799	-0.004	-0.104	0.002	0.823
Other	-0.003	-0.017	0.000	0.113	-0.004	-0.002	0.000	0.021
Marital status								
Yes	1.000				1.000			
No	-0.012	-0.409	0.020	10.500	-0.012	-0.434	0.021	11.673
Region of Residence								
Northeast	1.000				1.000			
Midwest	-0.005	-0.015	0.000	0.143	-0.003	-0.018	0.000	0.121
South	-0.008	-0.051	0.002	0.789	-0.002	-0.076	0.001	0.298
West	-0.018	0.045	-0.003	-1.648	-0.017	0.066	-0.004	-2.424
Household income								
Less than $10,000	1.000				1.000			
$10,000 to less than $15,000	0.002	-0.217	-0.002	-1.023	0.003	-0.207	-0.003	-1.367
$15,000 to less than $20,000	0.006	-0.243	-0.006	-2.939	0.005	-0.234	-0.005	-2.604
$20,000 to less than $25,000	0.011	-0.229	-0.010	-5.334	0.011	-0.224	-0.010	-5.408
$25,000 to less than $35,000	0.021	-0.133	-0.011	-5.815	0.017	-0.158	-0.011	-6.003
$35,000 to less than $50,000	0.028	0.078	0.009	4.490	0.027	0.008	0.001	0.460
$50,000 to less than $75,000	0.030	0.277	0.033	17.235	0.032	0.241	0.030	16.792
$70,000 or more	0.041	0.641	0.104	53.763	0.049	0.725	0.143	78.640
Education								

Did not graduate high school	1.000				1.000			
Graduated High School	0.018	-0.242	-0.017	-8.972	0.013	-0.196	-0.010	-5.610
Attended College	0.017	0.018	0.001	0.618	0.021	0.051	0.004	2.367
Graduated from College	0.031	0.471	0.059	30.554	0.024	0.413	0.039	21.414
Exercise in past 30 days								
No	1.000				1.000			
Yes	0.033	0.206	0.027	13.913	0.031	0.217	0.027	14.760
Smoking Status								
Current smoker	1.000				1.000			
Former smoker	0.058	0.072	0.017	8.694	0.051	0.051	0.010	5.746
Never smoked	0.044	0.026	0.005	2.377	0.042	0.057	0.010	5.261
Concentration index (CI)		0.193				0.181		

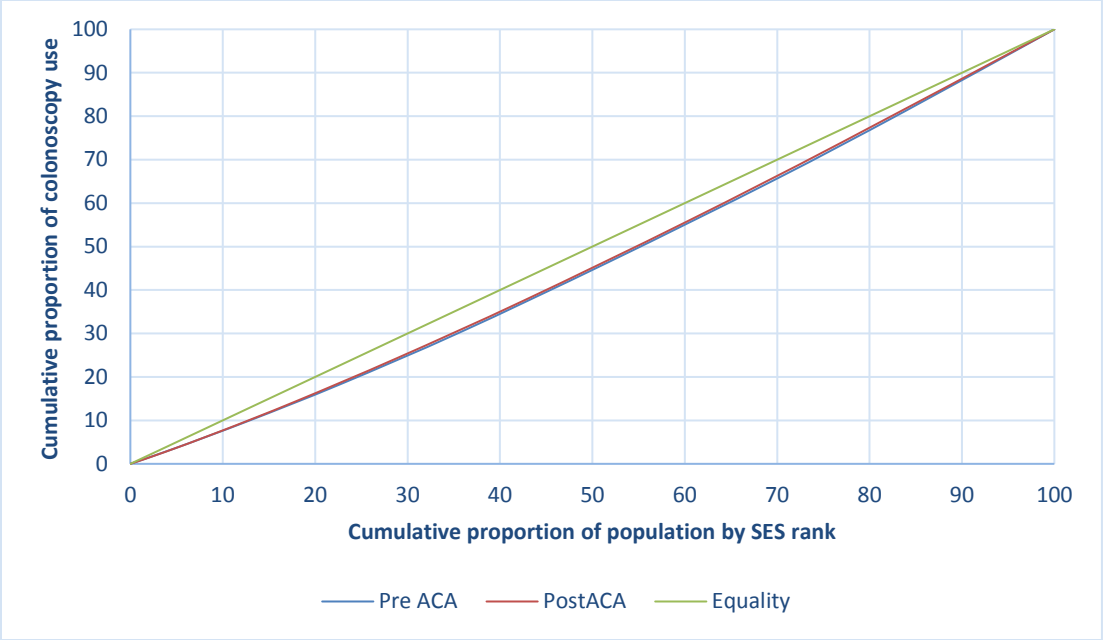

Figure 4.6. Concentration curve of colonoscopy use by rank of individuals by household income level

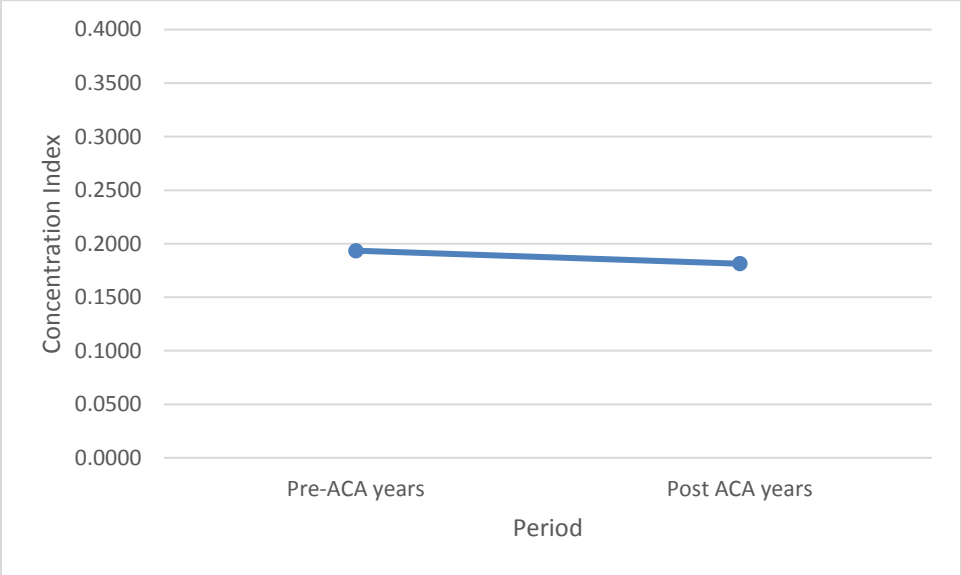

Figure 4.7 Concentration Index for colonoscopy use

CHAPTER 5

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

The results of this study indicated that the use of colonoscopies increased among the elderly insured after the implementation of the ACA cost-sharing rule for preventive services. The receipt of colonoscopies among the elderly insured increased from 64% in pre-ACA years to 69% in post-ACA years. After controlling for a number of individual and geographic factors, we found that elderly insured in the age group 65 to 75 years were 1.15 times more likely to be up-to-date with colonoscopy screenings than they were before implementation of the ACA. Although the analysis could not incorporate out-of-pocket expenses directly into the model due to lack of data, it is likely that the increase in colonoscopy uptake observed in the post-ACA years was due to reduction in cost-sharing. Increased coverage of colonoscopies appeared to be more pronounced among elderly insured who were less educated and in lower household income groups. In fact, increases in colonoscopy uptake were greatest among the lower income and lower education groups when comparing pre-ACA percentages to post-ACA percentages. However, even with higher coverage of colonoscopies after ACA implementation, only about half of the elderly insured in the age group 65-75 years with a household income less than $15,000 received a recommended colonoscopy. In fact, post-ACA implementation, 56% of elderly insured aged 65-75 years without a high school diploma

had received a colonoscopy in the last 10 years. Even after significant reductions in out-of-pocket expenses for colonoscopy receipt, the coverage of colonoscopies remains suboptimal; it is much lower than the national goal of 80% by 2018 and the HP2020 goal of 71%. To achieve a higher rate of progress toward the national goal, we must identify specific approaches that encourage socioeconomically disadvantaged elderly to seek colonoscopies.

However, we must stress again that our study did find a significant increase in colonoscopy use among elderly insured with lower socioeconomic status after implementation of the ACA. The increase may, in part, have been due to the removal of out-of-pocket costs, since previous studies found that financial barriers reduced coverage of cancer screening (Busch, Barry et al. 2006, Goodwin and Anderson 2012, Hamman and Kapinos 2015), and colonoscopies are expensive (Pyenson, Scammell et al. 2014). It is also possible that the increase in the receipt of colonoscopies among lower socioeconomic groups reflected both the continued increase of nationwide trends that and the proliferation of private health plans (Klabunde, Cronin et al. 2011, Shapiro, Klabunde et al. 2012, Wernli, Hubbard et al. 2014). The increase in CRC screenings was clearly universal across socioeconomic status and was not limited to subjects with lower income and lower levels of education. However, despite the improvements in colonoscopy uptake over the years, the poorest and the most socially disadvantaged groups represented the highest potential for improvement, given their relatively low rates of colonoscopy use. To achieve the target screening rate, policy makers must use additional interventions beyond lowering the barriers to access.

Our study results in the second manuscript suggested a significant income-related disparity in the use of colonoscopies among the elderly insured aged 65 to 75, and that disparities in colonoscopy use were lessened after the implementation of the ACA. We found that income and educational attainment levels were the major contributors to the existing disparity in the use of colonoscopies. Decomposition showed that the highest income group was consistently the largest contributor to the disparity in pre-ACA colonoscopy receipt (54%) and in post-ACA colonoscopy receipt (79%), and that having a college degree contributed approximately 31% to the observed disparities in pre-ACA years and 21% in post-ACA years.

Since income appears to be such a significant factor, policy makers should focus on the further reduction of financial barriers in colonoscopy use among the elderly insured. Eliminating cost-sharing for therapeutic colonoscopies could be the next policy reform to be considered in improving adherence to CRC screening guidelines (Hamman and Kapinos 2015).

Policy makers must also consider non-medical costs in order to improve screening rates more rapidly. Cost is not the only barrier to receipt of colonoscopies. Other barriers include perceived loss of utility associated with bowel preparation prior to the test, logistical challenges, lack of a physician's recommendation for CRC screening, and belief that CRC screening is unimportant or unnecessary (Benarroch-Gampel, Sheffield et al. 2012, Centers for Disease Control and Prevention 2013, Courtney, Paul et al. 2013, Howard, Guy et al. 2014, Ramdass, Petraro et al. 2014, Hamman and Kapinos 2015, Partin, Gravely et al. 2016, Grzywacz, Hussain et al. 2017) .

Research has shown that patients' perception of insurance coverage can deter them from receipt of CRC screening (Courtney, Paul et al. 2013, Zhao, Okoro et al. 2018). This indicates a need for improved awareness of the ACA's cost-sharing reduction provision among the elderly insured population. The Medicare program should ensure that all Medicare beneficiaries are aware of the new policy, which states that Part B provides screening colonoscopies with no deductible or coinsurance.

Another problem to address is that individuals with low income and/or unstable employment may have more difficulty in leaving work to receive preventive services. A previous study assessed the patterns and reasons for missed work related to screening colonoscopies, and the researchers found that 34% of working individuals missed work more than one day when they had their screening on a Tuesday, Wednesday, or Thursday. According to the study, 32% of participants requested sick or vacation leave for the day prior to the screening, mainly in anticipation of the bowel preparation; 10% requested leave for the day after the procedure, primarily as a precautionary measure following sedation rather than in response to true symptoms; and 9% requested leave for both days.

Finally, colonoscopy procedures require a significant amount of time investment from friends and family members. 45% of individuals had friends or family members who also took leave from work because of the procedure (Dong, Kalmaz et al. 2011). All these non-medical costs may be diminished through patient education about bowel preparation and what to expect before and after the procedure, and by scheduling more screening colonoscopies on Monday and Fridays (Dong, Kalmaz et al. 2011).

Researchers and policy makers have studied the effects of cost-sharing reductions on the utilization of preventive health care in great detail, but surprisingly, only a few studies have assessed the effect of cost-sharing reductions on colonoscopies among elderly insured (including Medicare beneficiaries), following the implementation of the ACA (Hamman and Kapinos 2015, Cooper, Kou et al. 2016). The few studies that have examined this issue used a very short time-frame beginning with the implementation of the ACA, so they may have underestimated the effects of the ACA cost-sharing reduction. Furthermore, these studies yielded variable results concerning the receipt of colonoscopies following the changes in coverage post-ACA (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Cooper, Kou et al. 2016); and they did not determine whether eliminating financial barriers to the receipt of colonoscopies might affect socioeconomically vulnerable Medicare beneficiaries more than it affected other groups. Moreover, these studies did not examine the ACA's impact on screening disparities among the elderly insured. It is true that some of the socioeconomically vulnerable elderly may be enrolled in Medicaid; and in those cases, the individuals would have received colonoscopies with no out-of-pocket expenses in the pre-ACA years. However, this should not affect the results of our study significantly as almost all elderly are enrolled in Medicare and only a relatively small percentage are enrolled in Medicaid (meaning Medicaid only or dually eligible) (Grabowski, 2012). Thus, to address these gaps in current research, this study examined the changes in colonoscopy use among the elderly insured population, including Medicare beneficiaries, following the implementation of the ACA policy for preventive services.

Previous studies found divergent results regarding post-ACA changes in CRC screenings among the elderly and Medicare beneficiaries (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015, Han, Robin Yabroff et al. 2015, Cooper, Kou et al. 2016). Some studies found an increase in the receipt of CRC screenings (Fedewa, Goodman et al. 2015, Hamman and Kapinos 2015), while others found no change in the use of any cancer screening procedure (Han, Robin Yabroff et al. 2015, Cooper, Kou et al. 2016). However, unlike these studies, our study had access to a longer time frame, which allowed us to examine the effects of ACA policy changes on colonoscopy use in greater detail. Using a longer time frame, and controlling for many other potential factors affecting colonoscopy uptake (including the availability of health care providers in the area – a variable never used before), we found a significant effect of policy change on colonoscopy use. The new supply-side variable showed us that the availability of GIs in a geographic area did affect the likelihood of receiving a colonoscopy within the recommended time frame. We also enhanced the body of evidence surrounding changes in income-related disparities in colonoscopy use among the elderly insured from pre-ACA years to post-ACA years. Our findings indicate that the ACA's removal of financial barriers may contribute to the observed decrease in the disparity of colonoscopy use.

This study has several limitations. First, the BRFSS is based on self-reports, which may be subject to recall bias. True screening rates are more likely less than 50% for adults aged 50 or older (Paskett and Khuri 2015). Therefore, we faced a challenge in establishing an accurate level of CRC screenings; and we were unable to perform a cross-check with medical records using current data (Ferrante, Ohman-Strickland et al. 2008, Schenck, Klabunde et al. 2008). Second, there is also the possibility of selection bias in

this type of survey, as less-healthy patients may not be included in the sample. Third, the BRFSS does not include information about actual out-of-pocket expenditures or other possible determinants of screening such as opportunity, cost of time or difficulty in scheduling colonoscopies. Fourth, this study could not distinguish between screening and diagnostic colonoscopies. Nonetheless, given the fact that around 40% of adults who should receive CRC screenings do not receive them (Joseph, King et al. 2012, Hamman and Kapinos 2015, Paskett and Khuri 2015), finding an increase in all types of colonoscopies as a result of the Affordable Care Act does suggest an improvement in CRC detection. Fifth, gastroenterologists are not the only providers of colonoscopy, and licensed providers vary by region (Benarroch-Gampel, Sheffield et al. 2012, Joseph, Meester et al. 2016). Sixth, there may be historical threats to validity. Increasing awareness over time and social norms in support of CRC may affect the rate of colonoscopy use. Seventh, this study could not assess public awareness of CRC. Finally, in 2011 BRFSS changed its weighting methodology with the inclusion of cellular phone-only respondents. Cellular phone respondents are likely to be different from other respondents in terms of age and risk of CRC. Therefore, this additional approach of selecting respondents may have affected the sample of 2011 compared to samples from the pre-2011 period.

In summary, our results confirmed that there was a statistically significant increase in colonoscopy use among the elderly insured aged 65 to 75 years after the implementation of the ACA. There was a significant income-related disparity in the use of colonoscopies among the insured elderly aged 65 to 75, and disparities in colonoscopy use lessened after the implementation of the ACA. Income and educational attainment

levels were the major contributors to those disparities which still exist. Although Medicare waived Part B deductibles for all colonoscopies and eliminated coinsurance for screening colonoscopies, individuals are still subject to out-of-pocket medical expenses for therapeutic colonoscopies (Hamman and Kapinos 2015). Our results indicate that the ACA's reduction of financial barriers has improved usage of CRC screening, and further improvements will be possible if the costs associated with therapeutic colonoscopies can be reduced or eliminated. Policy makers should also try to understand other related expenses, both medical and non-medical, associated with the receipt of colonoscopies by the elderly (Dong, Kalmaz et al. 2011, Petryszyn, Kempinski et al. 2014). Reducing these costs will also help achieve the national target rate of colonoscopy use. Interventions aimed at reducing disparities should focus on improving screening in populations with low household incomes and low educational attainment. Moreover, our results indicate that greater provider supply has been associated with increased use of colonoscopies. An increased supply of providers may have little beneficial effect on race and ethnic disparities in the receipt of colonoscopies or on geographic disparities in the receipt of colonoscopies (Benarroch-Gampel, Sheffield et al. 2012, Eberth, Josey et al. 2017). Interventions should focus on improving screening in populations living in rural areas and among minorities. A recent study reported that the estimated colonoscopist capacity was sufficient to screen 80% of the eligible U.S. population (Joseph, Meester et al. 2016). However, colonoscopies vary in quality, and high-quality colonoscopies take considerably more time than that which the average physician spends on such a procedure (Vicari 2010). If a particular area has a short supply of gastroenterologists,

short-run alternatives may be possible, such as training primary care providers to conduct colonoscopies (Selby, Cornuz et al. 2016).

The results of this study indicated that the use of colonoscopies increased among the elderly insured after the implementation of the ACA cost-sharing rule for preventive services. Reduction of financial barriers has been effective in improving CRC screening, and further reduction in financial barriers is likely to improve uptake of CRC screening in the future. The financial barriers are due not only to medical care costs but also to other non-medical expenses, and policy makers should consider how to improve access to preventive services by considering all the potential barriers to access. In general, lowering out-of-pocket expenses for colonoscopies has improved receipt of colonoscopies by all elderly groups; but the increase in coverage was higher for poorer individuals and individuals with low educational attainment. Therefore, reduction in out-of-pocket expenses benefited the disadvantaged elderly population at a higher rate than other elderly groups.

This study will contribute to advancing knowledge about the effect of reduction in cost-sharing on the receipt of colonoscopies among the elderly insured. It is critically important to know whether reduction of financial barriers alone can improve adherence to CRC screenings in order to achieve the national goal of 80% by 2018 target and the HP2020 goal of 71%. Reduction in financial expenses alone may not be enough to reach the goal, in which case these analyses will be able to indicate other policy options for improving coverage of colonoscopies. The study will provide scientific evidence on effect of cost-sharing reduction on the receipt of colonoscopies among the elderly insured as well as other policy options for improving adherence to CRC screening.

Under current law, Medicare waives coinsurance and deductibles for colonoscopies. However, when a polyp is discovered and removed, the procedure is reclassified as therapeutic for Medicare billing purposes and beneficiaries become responsible for paying 20% coinsurance. Therefore, Medicare beneficiaries may face unexpected out-of-pocket liabilities when a polyp is detected and removed during a colonoscopy. The Removing Barriers to Colorectal Cancer Screening Act of 2017 (H.R. 1017/S. 479 worked to correct an oversight in current law that requires Medicare beneficiaries to cover the cost of their copayment for a free screening colonoscopy if a polyp was discovered and removed during the procedure. This study will provide scientific evidence regarding the benefits of cost-sharing reductions on the receipt of colonoscopies among Medicare beneficiaries, thus supporting the Congressional bill which proposes to close remaining Medicare loophole. As a next step, we will prepare a manuscript to submit for the *American Journal of Public Health* and then a second manuscript to submit to *Medical Care*. I will also share my findings, including policy implications, at the American Public Health Association annual meeting in 2018. Finally, this dissertation will lay a foundation for a grant I plan to pursue (from, for example, an R03 small research grant program) to conduct a more in-depth investigation of racial and ethnic disparities in colonoscopy use in relation to physician availability.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD LETTER

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
DECLARATION of NOT HUMAN SUBJECTS

Min Jee Lee
Arnold School of Public Health
Department of Health Services Policy & Management
915 Greene Street
Columbia, SC 29208

Re: **Pro00075639**

Dear Ms. Lee:

This is to certify that Research Proposal entitled, ***The Effect of the Affordable Care Act on Receipt of Colonoscopy Among Medicare Beneficiaries,*** was reviewed on **02/22/2018** by the Office of Research Compliance, an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). The Office of Research Compliance, on behalf of the Institutional Review Board, has determined that the referenced study meets the Not Human Research criteria set forth by the Code of Federal Regulations
(45 CFR 46) of:

a. the specimens and/or private information/data were not collected specifically for the currently proposed research project through an interaction/intervention with living individuals AND

b. the investigator(s) including collaborators on the proposed research cannot readily ascertain the identity of the individual(s) to whom the coded private information or specimens pertain

No further oversight by the USC IRB is required; however, the investigator should inform the Office of Research Compliance prior to making any substantive changes in the research methods, as this may alter the status of the project.

If you have questions, contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
ORC Assistant Director
and IRB Manager