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Assessing the impact of multicomponent interventions on colorectal cancer screening through simulation: What would it take to reach national screening targets in North Carolina?

Karen Hicklin[a,*], **Meghan C. O'Leary**[b,c], **Siddhartha Nambiar**[d], **Maria E. Mayorga**[e], **Stephanie B. Wheeler**[b,c,f], **Melinda M. Davis**[g,h,i], **Lisa C. Richardson**[j], **Florence K.L. Tangka**[j], **Kristen Hassmiller Lich**[b]

[a]Department of Industrial and Systems Engineering, Herbert Wertheim College of Engineering, University of Florida, Gainesville, FL, USA

[b]Department of Health Policy & Management, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[c]Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[d]Covalent Solutions, LLC., Rockville MD, USA

[e]Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, NC, USA

[f]Center for Health Promotion & Disease Prevention, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[g]Oregon Rural Practice-based Research Network, Oregon Health & Science University, Portland, OR, USA

[h]Department of Family Medicine, Oregon Health & Science University, Portland, OR, USA

[i]School of Public Health, Oregon Health & Science University, Portland State University, Portland, OR, USA

[j]Centers for Disease Control and Prevention, Atlanta, GA, USA

[*]Corresponding author at: Department of Industrial and Systems Engineering, Herbert Wertheim College of Engineering, University of Florida, 446A Weil Hall, PO Box 116595, Gainesville, FL 32611-6595, USA. khicklin@ufl.edu (K. Hicklin).

CRediT authorship contribution statement

Karen Hicklin: Conceptualization, Formal analysis, Investigation, Methodology, Original draft preparation, Writing – original draft, Visualization, Validation, Writing – review & editing. **Meghan C. O'Leary:** Conceptualization, Writing – original draft, Writing – review & editing, Methodology, Validation. **Siddhartha Nambiar:** Formal analysis, investigation, validation. **Maria E. Mayorga:** Conceptualization, Formal analysis, Investigation, Validation, Writing – review & editing. **Stephanie B. Wheeler:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing, Supervision. **Melinda M. Davis:** Conceptualization, Methodology, Writing – review & editing. **Lisa C. Richardson:** Conceptualization, Methodology, Writing – review & editing. **Florence K.L. Tangka:** Conceptualization, Methodology, Writing – review & editing. **Kristen Hassmiller Lich:** Conceptualization, Methodology, Validation, Writing - review & editing, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107126.

Declaration of Competing Interest

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Abstract

Healthy People 2020 and the National Colorectal Cancer Roundtable established colorectal cancer (CRC) screening targets of 70.5% and 80%, respectively. While evidence-based interventions (EBIs) have increased CRC screening, the ability to achieve these targets at the population level remains uncertain. We simulated the impact of multicomponent interventions in North Carolina over 5 years to assess the potential for meeting national screening targets. Each intervention scenario is described as a core EBI with additional components indicated by the "+" symbol: patient navigation for screening colonoscopy (*PN-for-Col+*), mailed fecal immunochemical testing (*MailedFIT+*), MailedFIT+ targeted to Medicaid enrollees (*MailedFIT + forMd*), and provider assessment and feedback (*PAF+*). Each intervention was simulated with and without Medicaid expansion and at different levels of exposure (i.e., reach) for targeted populations. Outcomes included the percent up-to-date overall and by sociodemographic subgroups and number of CRC cases and deaths averted. Each multicomponent intervention was associated with increased CRC screening and averted both CRC cases and deaths; three had the potential to reach screening targets. *PN-for-Col +* achieved the 70.5% target with 97% reach after 1 year, and the 80% target with 78% reach after 5 years. *MailedFIT+* achieved the 70.5% target with 74% reach after 1 year and 5 years. In the Medicaid population, assuming Medicaid expansion, *MailedFIT + forMd* reached the 70.5% target after 5 years with 97% reach. This study clarifies the potential for states to reach national CRC screening targets using multicomponent EBIs, but decision-makers also should consider tradeoffs in cost, reach, and ability to reduce disparities when selecting interventions.

Keywords

Simulation; Modeling; Colorectal cancer screening; Multicomponent interventions; Population-level outcomes; Targets

1. Introduction

Increased colorectal cancer (CRC) screening has contributed to declining rates of CRC incidence and mortality in the U.S. (Bibbins-Domingo et al., 2016; U.S. Cancer Statistics Working Group, 2020). Although the annual CRC incidence rate decreased by 19.3 per 100,000 people, and the mortality rate decreased by 7.4 per 100,000 people between 1999 and 2017 (U.S. Cancer Statistics Working Group, 2020), the national burden of CRC remains relatively high with an estimated 149,500 new diagnoses and 53,000 deaths in 2021 (Siegel et al., 2021). In 2018, 68.8% of adults ages 50–75 (i.e. ages recommended for screening by the U.S. Preventive Services Task Force prior to 2021) reported being up-to-date (UTD) with CRC screening (Centers for Disease Control and Prevention (CDC), 2019), typically by colonoscopy within the past ten years or a stool test (e.g., fecal immunochemical test (FIT)) within the past year. Healthcare providers, policymakers, and other stakeholders are still working to achieve national CRC screening targets of 70.5% set by Healthy People 2020 (Office of Disease Prevention and Health Promotion, 2019) and 80% set by the National Colorectal Cancer Roundtable (NCCRT) (National Colorectal Cancer Roundtable, 2019). Additional efforts are needed to achieve these targets overall and in subpopulations experiencing greater barriers to accessing care (e.g., low-income,

uninsured, underserved patients) (Wang et al., 2019; Martens et al., 2016; Muthukrishnan et al., 2019). For example, only 44.1% of age-eligible patients served by safety-net federally qualified health centers (FQHCs) were UTD with CRC screening in 2018 (National Colorectal Cancer Roundtable, 2020).

To support greater gains in CRC screening, the Community Guide recommends implementing multicomponent evidence-based interventions (EBIs) - those that combine at least two components intended to increase the demand for, access to, and/or provider delivery of screening services (Community Preventive Services Task Force, 2016). In their systematic review, the Community Preventive Services Task Force found that multicomponent interventions increased CRC screening by a median of 15.4 percentage points (interquartile interval: 6.0 to 21.6 percentage points), versus no intervention (Community Preventive Services Task Force, 2016). Other systematic reviews (Dougherty et al., 2018; Davis et al., 2018) have similarly reported the benefits of multicomponent interventions.

Our team previously used microsimulation modeling to project how different interventions would affect population-level CRC screening rates (Hassmiller Lich et al., 2017; Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020). We demonstrated that implementing single EBIs (e.g., mailed reminders) (Hassmiller Lich et al., 2017; Davis et al., 2019) and expanding Medicaid (Hassmiller Lich et al., 2019; Powell et al., 2020), separately, were effective in increasing CRC screening rates and reducing CRC cases. However, none of the previously simulated scenarios were sufficient on their own for achieving national screening targets.

This analysis was designed to utilize microsimulation to estimate and compare the effectiveness of *multicomponent* EBIs, alone and in combination with Medicaid expansion, to determine which approaches could achieve national CRC screening targets among overall populations of age-eligible individuals within North Carolina. We selected multicomponent EBIs that represent a diverse collection of strategies being considered by state- and national-level decision-makers that are anticipated to result in significant gains in CRC screening. Simulation of these bundled intervention components allowed us to assess the feasibility of achieving national screening targets. Secondary analysis studied their relative impact on CRC screening disparities by gender, race, ethnicity, rurality, age, and insurance.

2. Methods

We used an individual-based microsimulation model to assess whether multicomponent interventions could surpass the 70.5% and 80% screening targets in North Carolina (NC). We focused specifically on NC because we have claims data available on population demographics and screening patterns among state residents, the population is diverse, and it is one of only 12 states that has yet to expand Medicaid (Kaiser Family Foundation, 2021). We simulated CRC screening outcomes for the full NC population during a 5-year period (January 1, 2020 - December 31, 2024) in patients age-eligible for CRC screening (50–75 years in 2020). The synthetic NC population was simulated from birth until death using U.S. Census Bureau data, including biological factors (e.g., development and

progression of polyps and CRC) and behavioral factors (e.g., probability of completing routine CRC screening) and policy/personal factors such as insurance coverage (e.g., uninsured, Medicaid, Medicare, Commercial). As with our prior work (Hassmiller Lich et al., 2017; Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020; Wheeler et al., 2018), sociodemographic characteristics (e.g., age, sex, race, insurance status, geographic location), based on claims data, were used to predict simulated individuals' likelihood of screening for CRC, choice of modality, disease incidence, and life-expectancy (Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020; Nambiar et al., 2018; Wheeler et al., 2018). Additional details regarding our model assumptions, validation, and uses were previously reported in the supplement (Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020; Nambiar et al., 2018; Wheeler et al., 2018).

2.1. Multicomponent interventions simulated

We selected multicomponent interventions to simulate based on a literature review of multicomponent EBIs that best matched the demographics of the simulated population (Community Preventive Services Task Force, 2016), findings from our team's prior work simulating individual EBIs (Hassmiller Lich et al., 2017; Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020), and discussions with decision-makers at state and national levels. Our goal was to select evidence-based scenarios that reflect the diversity of options being weighed by decision-makers, including whether to implement interventions that: 1) promote a specific screening modality (e.g., colonoscopy vs. FIT), 2) reach patients directly (e.g., mailed FIT programs) versus clinic-based interventions (e.g., provider assessment and feedback), and 3) target the overall population versus specific subpopulations with lower documented screening rates (e.g., Medicaid enrollees). Additionally, we wanted to simulate ambitious multicomponent interventions – those most likely to result in large gains in screening. While ambitious interventions may be more resource-intensive and require system changes, we aimed to simulate interventions with the highest potential to achieve national screening targets. From prior work, we learned that less intensive interventions cannot surpass established population-level targets on their own (Hassmiller Lich et al., 2017; Davis et al., 2019; Hassmiller Lich et al., 2019; Powell et al., 2020; Nambiar et al., 2018).

Table 1 describes the four multicomponent interventions simulated; each of which bundles together at least two EBI components recommended by the Community Guide (Community Preventive Services Task Force, 2016). We refer to each scenario using its primary core intervention component and include a "+" to indicate that additional EBI components were included. The first is a mailed FIT program *(MailedFIT+)* (Levy et al., 2013; Jean-Jacques et al., 2012; Myers et al., 2013), which includes the mailing of FIT kits to eligible patients' homes as well as patient and provider reminders. The second is patient navigation to colonoscopy *(PN-for-Col+)* (Percac-Lima et al., 2009; Honeycutt et al., 2013), where patients are encouraged to screen specifically by colonoscopy; patient education and patient and provider reminders are also included. The third is a provider assessment and feedback program (*PAF+*) (Tangka et al., 2019), where providers are evaluated on and receive feedback about their performance delivering CRC screening services (Community Preventive Services Task Force, 2016; Lara et al., 2018). *PAF+* includes other quality

improvement efforts at the health system or practice level, such as patient and provider reminders. The fourth is a targeted mailed FIT program that specifically aims to increase CRC screening among Medicaid enrollees (*MailedFIT + Md)* through mailed FIT kits, patient reminders, and navigation to diagnostic follow-up if needed (Dougherty et al., 2018; Gupta et al., 2013; Goldman et al., 2015). We compared each of these multicomponent interventions to usual care (i.e., no intervention).

We simulated each of the multicomponent interventions with and without Medicaid expansion. Adding Medicaid expansion to each scenario allowed us to evaluate the incremental advantage of expanding insurance coverage on CRC screening. This step was important because access to (and type of) insurance are known predictors of CRC screening (Petrik et al., 2018; Zhao et al., 2018; de Moor et al., 2018) and because NC has not expanded its Medicaid program (The Henry J. Kaiser Family Foundation, 2018). In the Medicaid expansion scenarios, we assumed the income eligibility limit for Medicaid increased to 138% of the federal poverty level, consistent with eligibility criteria in Medicaid expansion states.

We also modeled intervention reach, defined as the proportion of the targeted population exposed to the intervention, consistent with the RE-AIM framework (Glasgow, 2018). We simulated each multicomponent intervention, assuming five reach levels: 0% (usual care), 25%, 50%, 75% and 100%. These values for reach represent an ideal case scenario for implementation (100% of eligible patients reached) through levels of exposure seen in prior real-world implementation studies (25% to 75% of eligible population reached) (Green et al., 2019; Petrik et al., 2020). We conducted a threshold analysis to determine specific levels of reach needed to achieve screening targets. For the *MailedFIT+*, *PN-for-Col+*, and *PAF+* intervention scenarios, the eligible population included NC residents aged 50–75 not UTD with CRC screening, insured or received care from an FQHC (estimated from 2018 to 2019 NC data) if uninsured (Engel-Smith, 2019; U.S. Census Bureau, n.d.; HRSA Data Warehouse, n.d.). The eligible population for the *MailedFIT + forMd* scenario included only Medicaid enrollees aged 50–64 who were not UTD with CRC screening; however, the percent UTD is still reported for the full age-eligible NC population to be comparable to other population-level screening strategies.

2.2. Intervention effectiveness and screening modality

In the usual care scenario, logistic regression was used to assign a predetermined probability of receiving CRC screening and preferred screening modality (either FIT or colonoscopy) to everyone in the model. Both the screening probability and modality were based on county-level and individual-level attributes observed in NC claims data (Wheeler et al., 2014) and accounted for demographic and contextual factors (Wheeler et al., 2017). To estimate the effectiveness of each multicomponent intervention, individuals' predetermined probability of receiving CRC screening was multiplied by the respective intervention's relative risk (RR), a statistical representation of the intervention's impact in increasing CRC screening compared to usual care across available studies for each multicomponent intervention (Table 1), with an upper bound probability of 1. We sampled RR from a lognormal distribution generated using average, minimum, and maximum RR to parameterize the distribution.

Individuals aged 50–75 were considered UTD with CRC screening if they received a FIT in the prior year or a colonoscopy in the past 10 years, per current guidelines in 2020 (Bibbins-Domingo et al., 2016). We assumed that intervention implementation could affect individuals' preferred screening modality and predicted probability of screening by their preferred modality (e.g., the *MailedFIT*+ intervention may prompt some with a preferred modality of colonoscopy to screen with FIT). The supplement provides additional information about modeling screening modality.

2.3. Simulation outcomes and analyses

We identified the multicomponent interventions capable of achieving the 70.5% and 80% screening targets by level of reach and, for those that achieve the targets, the specific level of reach needed. We report the percent UTD overall and by sociodemographic subgroups. Additionally, we present the effect of varying RR values on the percent UTD as a function of reach. Longer-term health outcomes include CRC cases averted by cancer stage and CRC-specific deaths averted over simulated individuals' lifetimes. The simulation model was run for 20 replications using AnyLogic (version 8.5.1).

3. Results

The demographic characteristics and insurance coverage of the NC population during the 5-year intervention period are presented in Supplemental Table 1. The size of the simulated age-eligible population increased from 2.8 to 3.2 million during this period, reflecting an aging population. The age distribution and insurance mix of the population shifted, with an increase of approximately 9 percentage points for individuals 65 years or older and an increase in the number of Medicare enrollees, consistent with NC demographic trends (Tippett, 2017; Trogdon and Raynor, 2017).

Fig. 1 displays the percent of the NC population UTD with CRC screening in the usual care and multicomponent intervention scenarios after 1 year and 5 years by level of intervention reach. Assuming no change in insurance access (Fig. 1a and b), the *MailedFIT*+ and *PN-for-Col* + interventions achieved the 70.5% UTD target after 1 year assuming 75% and 100% reach, respectively. *PN-for-Col* + was the only intervention to get to the 80% UTD target after 5 years, with 100% reach. Threshold analysis showed the minimum reach needed to meet these targets; the *PN-for-Col* + intervention achieved the 70.5% target after 1 year of intervention with 97% reach, and the 80% target after 5 years of intervention with 78% reach, while the *MailedFIT*+intervention surpassed the 70.5% target after 1 year and 5 years of intervention with 74% reach. Both the *PAF*+ and *MailedFIT* + *forMd* interventions were associated with increased UTD rates as the reach level increased but were not associated with sufficient gains to achieve either target in the overall population. The findings were similar with Medicaid expansion (Fig. 1c and d) with two important exceptions – 1) *PN-for-Col* +achieved the 80% target after 5 years with lower reach and 2) *MailedFIT* + *forMd* achieved the 70.5% target among Medicaid enrollees after 5 years with at least 97% reach.

Subgroup Analysis.

The impact of the multicomponent interventions on percent UTD in specific subpopulations after 5 years of intervention are presented in Table 2 (for 25% and 75% reach scenarios) and Supplemental Table 2 (all reach scenarios). With usual care, the UTD rate in the general population was 50.4%. Assuming 25% reach, the 70.5% target was achieved by the *PN-for-Col* + intervention in three subgroups – individuals aged 65+, privately insured, and Medicare enrollees. At 75% reach, *PN-for-Col* + reached the 70.5% target in every subgroup except the uninsured, and also surpassed the 80% target among females, whites, individuals aged 65+, privately insured, and Medicare enrollees. At this same reach level of 75%, the *MailedFIT*+ intervention achieved 70.5% screened for multiple subgroups (females, whites, urban residents, individuals aged 60+, privately insured, and Medicare enrollees), but was not able to achieve the 80% target in any population. Neither screening target was achieved in the subgroups assessed at 25% or 75% reach with the *MailedFIT* + *forMd* or *PAF*+ interventions.

3.1. Reach parameters and relative risk (RR)

We tested different combinations of reach parameter and RR values on the percentage of age-eligible adults UTD with CRC screening at 5 years (Fig. 2) to understand tradeoffs in implementation decisions. We focused specifically on the *MailedFIT*+ and *PN-for-Col* + interventions because they were capable of achieving current screening targets in the overall population. After 5 years of implementing *MailedFIT*+, the 80% UTD target in the overall population could be achieved with a RR of 4.0 and intervention reach of 75%, or a lower RR of 3.0 and a higher reach of 100%. After 5 years, *PN-for-Col* + could achieve the 70.5% UTD target with a RR of 1.5 and 40% reach, and the 80% UTD target with a RR of 2.5 and 100% reach.

3.2. Long-term outcomes

All interventions were associated with meaningful reductions in CRC cases for the NC simulated population, overall and by stage, and CRC-specific deaths, versus usual care (Table 3). Under usual care, over 161,000 CRC cases (58.8% diagnosed at Stage 3 or 4) and 79,000 CRC deaths were expected across the simulated individuals' lifetimes. The *PN-for-Col* + intervention was associated with the greatest reductions in CRC cases and deaths, followed by *MailedFIT*+, *PAF*+, and *MailedFIT* + *forMd,* across all reach values. While *MailedFIT* + *forMd* was associated with relatively small numbers of averted CRC cases and deaths without Medicaid expansion, we found a high impact in terms of reduced diagnoses and mortality when this intervention was combined with Medicaid expansion (Supplemental Table 3).

4. Discussion

This study demonstrated that it is possible, albeit difficult, for states to surpass the 70.5% and 80% population-level CRC screening targets through implementing multicomponent interventions. Of the four simulated interventions, two (*MailedFIT*+ and *PN-for-Col*+) were able to achieve at least the 70.5% target in the overall population. The large increases in population-level screening associated with a 5-year dose of each simulated intervention are

expected to produce substantial long-term health benefits (e.g., over 13,000 CRC cases and 6000 deaths averted for *PN-for-Col* + with only 25% reach).

While CRC screening targets were found to be attainable in our model, the ability to achieve these targets is conditional on intervention reach, previously identified as an important metric (Glasgow, 2018; Green et al., 2019). For example, at least 74% of the age-eligible population needed to be exposed to the *MailedFIT*+ intervention to surpass the 70.5% target. In practice, those implementing CRC screening interventions have reported a variety of implementation challenges–such as competing demands, staff turnover, technical challenges, limited funding, and problems developing streamlined processes with partner agencies–which can limit intervention reach (Hannon et al., 2019; Coronado et al., 2017). In a pragmatic trial using an electronic health system to administer a mailed FIT program in FQHCs, Green and colleagues (2019) reported wide variation in reach across health centers (4.8–74.7 primarily driven by health center characteristics (Green et al., 2019). Prior work has identified ways to optimize CRC screening programs (Coury et al., 2021; Davis et al., n.d.), but additional research is needed on how to improve multicomponent interventions implementation considering higher levels of reach.

Focusing solely on intervention effectiveness in increasing CRC screening at the population level may undermine efforts to eliminate existing disparities. Interventions that were more effective in the overall population were unable to achieve more equitable screening outcomes. For example, under the *PN-for-Col* + intervention assuming 50% reach, all insured populations achieved the 70.5% target, and privately insured subpopulations even achieved the 80% target, while the uninsured did not get to either target. Even when the *MailedFIT*+ intervention was assumed to reach 75% of the age-eligible population, multiple subgroups, including non-white individuals, Hispanics, rural residents, Medicaid enrollees, dual Medicaid/Medicare enrollees, and the uninsured, still fell short of the 70.5% target. These subpopulations have been shown to have relatively low screening rates (Wheeler et al., 2014; White et al., 2017; Davis et al., 2017; Joseph et al., 2020; Siegel et al., 2020); for example, CRC screening is 11 to 35 percentage points lower for Medicaid enrollees and the uninsured, respectively, compared to privately insured individuals (Siegel et al., 2020). While these simulated interventions are expected to increase overall CRC screening, targeted efforts are needed to adequately address screening disparities.

Our results underscore the need to prioritize strategies that better reach the uninsured population through targeted interventions and upstream policy changes to enhance access. It is notable that the uninsured were the only subgroup in this analysis in which screening targets of 70.5% and 80% could not be achieved during the 5-year period by any intervention – even when layering on Medicaid expansion. This is due, in part, to our assumption that the interventions would only be offered to uninsured individuals who seek care from FQHCs (approximately 51% of NC's uninsured population) (Engel-Smith, 2019; U.S. Census Bureau, n.d.; HRSA Data Warehouse, n.d.). Estimates suggest that 20–30% of newly eligible Medicaid patients have yet to establish with primary care (DeLia, 2021). Interventions that reach the uninsured, as well as Medicaid patients who have not established with primary care, are needed. The ability to meet screening targets is primarily impeded by the large inequities in access to CRC screening facing the uninsured. NC is one of only

12 states that has yet to expand Medicaid coverage (Kaiser Family Foundation, 2021). To make meaningful strides toward achieving national CRC targets, and to reduce existing disparities in screening rates by insurance, future interventions should include policy efforts to encourage Medicaid expansion and focus specifically on reaching individuals who are uninsured or have not established with primary care.

Decision-makers may need to consider the feasibility of implementing strategies given their budgets and local contexts. Of the four simulated interventions, *PN-for-Col* + was associated with the most substantial improvements in CRC screening and the largest reductions in CRC incidence and mortality – likely because colonoscopy provides UTD coverage for 10 years versus 1 year for FIT. However, this intervention may be cost-prohibitive in low-resource settings, compared to lower-cost options like mailed FIT programs. Prior simulation studies have shown that, given limited budgets, prioritizing FIT over colonoscopies is associated with higher intervention reach and greater reductions in CRC morbidity and mortality (Subramanian et al., 2010; van der Steen et al., 2015); an annual FIT-based program in South Carolina was expected to screen nearly 8 times more individuals for CRC and avert 4 times as many CRC-specific deaths than a colonoscopy screening program among the state's low-income and uninsured populations (van der Steen et al., 2015).

This analysis highlights the need to consider intervention targets carefully. For example, although the *PAF*+ scenario achieved a 3.31 and 11.23 percentage point UTD gain if 25% and 100% of the population was reached, respectively, its impact was expected to be more limited than direct outreach-focused interventions. The *PAF*+ intervention focuses primarily on addressing provider-level barriers to screening, whereas the *MailedFIT*+ and *PN-for-Col* + interventions are designed to reduce multilevel barriers to screening. To achieve national targets, our results suggest that provider-level, patient-level, and structural barriers to screening must be addressed.

This study has a few limitations. We focused on potential impact/effectiveness of multicomponent interventions but not costs. Since implementation costs affect the feasibility of intervention implementation, a cost-effectiveness analysis comparing these same scenarios is an important area for future work. For example, the *PN-for-Col* + intervention was the only one capable of achieving the 80% screening target, colonoscopies cost more than FIT tests (over $700 per colonoscopy versus about $20 per FIT) (Rice et al., 2019; Wheeler et al., 2020). Second, while our effectiveness estimates reflect best available evidence in prior literature, the reliability of these estimates across interventions may vary. More studies reported RR values for the *MailedFIT*+ intervention than the *PN-for-Col* + intervention. Third, our simulation was limited to patients aged 50–75. Given the shift in 2021 to expand screening to patients starting at 45 (Davidson et al., 2021), the impact interventions may differ in this younger population and warrants future study. Fourth, we assume the interventions have the same efficacy (or impact) each year it is offered. We have not modeled the potential waning efficacy of the interventions nor the impact screening in previous years have on present screening behavior. Lastly, our microsimulation model included assumptions, such as rules for how individuals select screening modalities. More work is needed to understand the impact of these assumptions.

Overall, this analysis provides promising evidence of the potential to reach population-level CRC screening targets through multicomponent interventions – if the interventions have sufficient reach. We found that the *PN-for-Col* + intervention can achieve the 70.5% target in 1 year and achieve the 80% target in 5 years, while the *MailedFIT*+ intervention can achieve the 70.5% target in 1 year. This analysis also illustrates that focusing on population-level screening target achievements may miss important subpopulations who are marginalized by healthcare systems and left behind in screening efforts seeking to optimize only the overall population target. When selecting interventions, decision-makers should consider the impact on existing inequities in CRC screening. In particular, tradeoffs between the opportunity to reach large proportions of the full population or targeted subpopulations with the screening intervention, including implementation resources such as costs and personnel time required for broader-scale implementation to increase intervention coverage.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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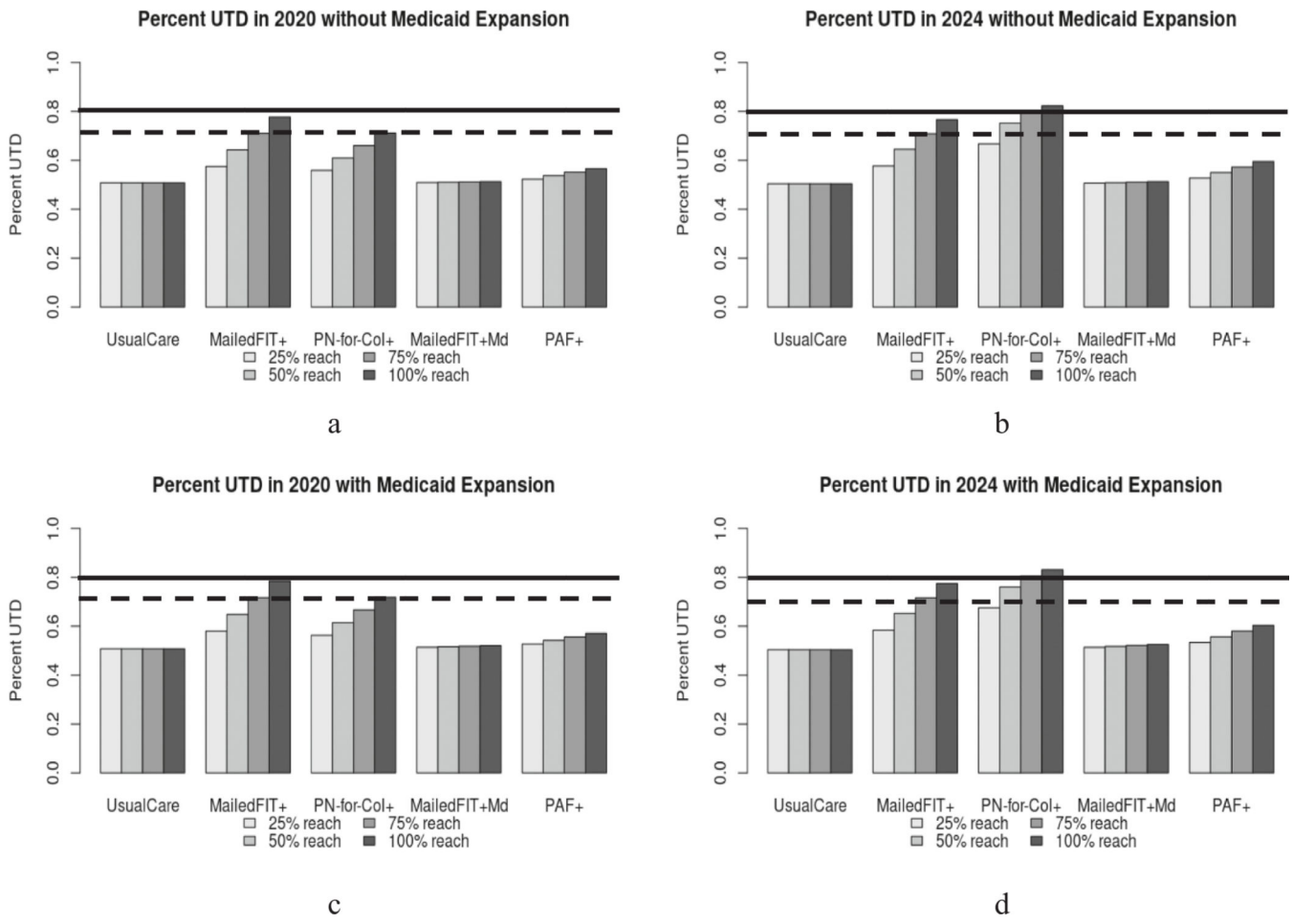

Fig. 1.

Percentage of simulated North Carolina population aged 50–75 up-to-date (UTD) with CRC screening by usual care and multicomponent intervention in 2020 (start of intervention period) and 2024 (end of intervention period) with and without Medicaid expansion and assuming different levels of intervention reach. The interventions are mailed fecal immunochemical testing (*MailedFIT+*), patient navigation for screening colonoscopy (*PN-for-Col+*), *MailedFIT+* targeted to Medicaid enrollees (*MailedFIT + forMd*), and provider assessment and feedback (*PAF+*). Solid lines indicate the 80% target and dashed lines indicate the 70.5% target.

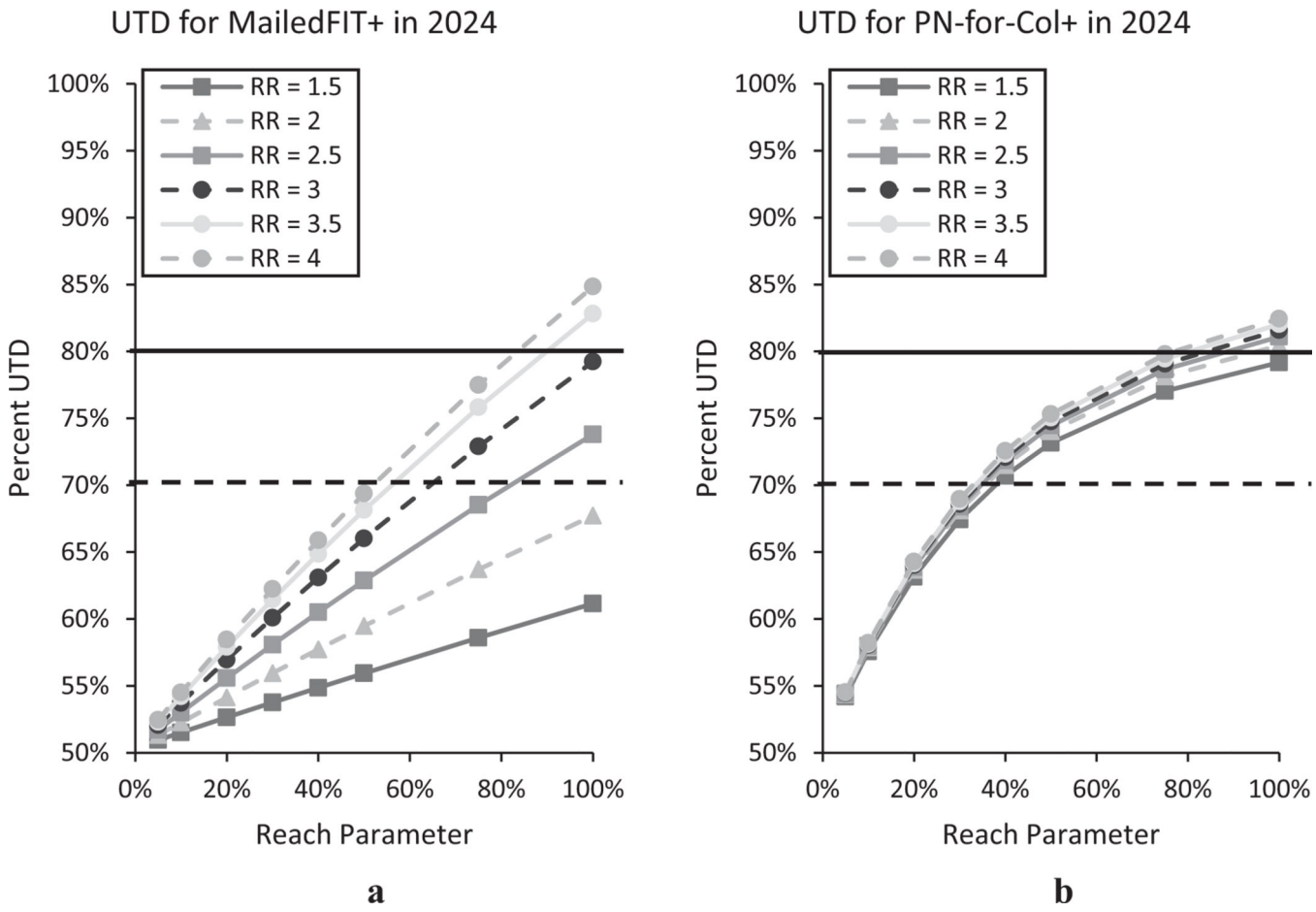

Fig. 2.

Relative risk curves for varying the percent up-to-date (UTD) and reach parameter combinations for the mailed fecal immunochemical testing (*MailedFIT+*) and patient navigation for screening colonoscopy (*PN-for-Col+*) interventions during the last year of intervention. The dashed lines and solid lines represent the 70.5% and 80% screening targets, respectively.

Table 1

Description of simulated multicomponent intervention scenarios. Each scenario is evaluated assuming Medicaid expansion and no Medicaid expansion, and different reach levels.

Multicomponent intervention scenario	Intervention target	Short description of multicomponent intervention	Average relative risk (min, max)	References
Mailed fecal immunochemical testing: *MailedFIT+*	Primary care clinics	Mailed FIT program, written patient reminders (e.g., CRC screening fact sheet), patient reminders by phone (i.e., structured call to provide education and address patients' questions about CRC screening) (Levy et al., 2013; Myers et al., 2013; Jean-Jacques et al., 2012), and provider reminders (i.e., physician chart reminder) (Levy et al., 2013).	2.75 (2.39, 3.21)	Levy et al. 2013, Jean-Jacques et al. 2012, Myers et al. 2013
Patient navigation for screening colonoscopy: *PN-for-col+*	Primary care clinics	Colonoscopy-favoring patient screening navigation in which navigators assist patients in overcoming barriers to screening (e.g., costs, transportation, literacy, having someone to accompany the patient), one-on-one education provided to patients by phone, patient reminders (e.g., written educational materials, appointment reminders) (Percac-Lima et al., 2009; Honeycutt et al., 2013), and provider reminders (electronic alerts to refer patients for screening) (Honeycutt et al., 2013).	3.78 (2.17, 5.39)	Percac-Lima et al. 2009, Honeycutt et al. 2013
Provider assessment and feedback: *PAF+*	Primary care clinics	Provider assessment and feedback (PAF) in which clinic-specific CRC screening rates are evaluated and providers receive feedback on how to improve their performance (Tangka et al., 2019; Lara et al., 2018).	1.47 (1.14, 1.86)	Tangka et al. 2019; Lara et al. 2018
MailedFIT+ targeted to Medicaid enrollees: *MailedFIT+ forMd*	Medicaid enrollees	Mailed FIT program, patient reminders by phone (automated calls and calls from navigators), and patient navigation to diagnostic colonoscopy if a positive FIT.	2.43 (2.40, 2.55)	Gupta et al. 2013; Goldman et al. 2015; Dougherty et al. 2018

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Table 2

Percentage point change in the percent of the simulated age-eligible population up-to-date with CRC screening by demographic and insurance characteristics after the 5-year intervention window (December 31, 2024), compared to usual care. Results are reported assuming that eligibility for the Medicaid program is not expanded and assuming 25% and 75% reach of the interventions. The 90% (5th percentile, 95th percentile) uncertainty interval provided for overall results only.

Reach	Characteristic	Usual care (referent)	Mailed FIT+	PN-for-col+	Mailed FIT + forMd	PAF+
25%	**Overall** (5th, 95th)	50.37% (50.32%, 50.43%)	+7.25 (7.14, 7.33)	+16.29 (16.19, 16.38)	+0.22 (0.15, 0.28)	+2.66 (2.56, 2.75)
	Gender					
	Male	49.22%	+6.81	+15.59	+0.25	+2.73
	Female	51.35%	+7.62	+16.89	+0.19	+2.60
	Race					
	White	51.29%	+7.29	+16.55	+0.15	+2.68
	Black	48.45%	+7.10	+15.71	+0.47	+2.63
	Other	44.87%	+7.19	+14.87	+0.32	+2.55
	Ethnicity					
	Hispanic	43.82%	+7.31	+14.98	+0.47	+2.67
	Geography					
	Urban	51.02%	+7.35	+16.01	+0.21	+2.32
	Rural	48.33%	+7.35	+17.36	+0.25	+2.34
	Age					
	50–54	42.42%	+8.40	+14.95	+0.45	+2.50
	55–59	46.52%	+8.26	+18.84	+0.38	+2.29
	60–64	48.96%	+8.05	+17.85	+0.31	+2.25
	65+	56.35%	+6.14	**+15.14**	+0.00	+2.30
	Insurance					
	Private	53.83%	+9.03	**+18.99**	+0.00	+3.12
	Medicare	56.96%	+6.13	**+15.11**	−0.01	+2.60
	Medicaid	41.70%	+7.98	+20.77	+6.72	+3.20
	Dual	47.98%	+6.11	+16.53	+0.03	+2.75
	Uninsured	18.09%	+4.90	+9.21	−0.01	+1.03
	Overall (5th, 95th)	50.37% (50.32%, 50.43%)	**+20.18** (20.10, 20.24)	**+29.16** (29.09, 29.24)	+0.66 (0.58, 0.72)	+7.86 (7.77, 7.91)

Reach	Characteristic	Usual care (referent)	Mailed FIT+	PN-for-col+	Mailed FIT + forMd	PAF+
75%	**Gender**					
	Male	49.22%	+18.95	**+28.33**	+0.75	+8.08
	Female	51.34%	**+21.22**	**+30.08** ^	+0.57	+7.67
	Race					
	White	51.28%	**+20.30**	**+29.49** ^	+0.45	+7.92
	Black	48.44%	+19.73	**+28.71**	+1.38	+7.75
	Other	44.89%	+19.97	**+28.41**	+0.95	+7.38
	Ethnicity					
	Hispanic	43.85%	+20.27	**+28.81**	+1.35	+7.59
	Geography					
	Urban	51.02%	**+20.45**	**+28.74**	+0.62	+6.88
	Rural	48.33%	+20.41	**+30.94**	+0.74	+6.94
	Age					
	50–54	42.42%	+23.92	**+31.17**	+1.31	+7.21
	55–59	46.52%	+23.05	**+32.07**	+1.14	+6.87
	60–64	48.96%	**+22.32**	**+30.24**	+0.93	+6.72
	65+	56.35%	**+16.82**	**+26.71** ^	+0.01	+6.85
	Insurance					
	Private	53.82%	**+25.19**	**+32.35** ^	+0.00	+9.16
	Medicare	56.96%	**+16.80**	**+26.53** ^	+0.00	+7.65
	Medicaid	41.71%	+22.47	**+37.75**	+19.75	+9.51
	Dual	47.97%	+17.05	**+30.18**	+0.12	+8.40
	Uninsured	18.08%	+14.28	+23.81	+0.00	+3.10

Mailed fecal immunochemical testing program (MailedFIT+); Patient navigation for screening colonoscopy (PN-for-Col+); MailedFIT+ targeted to Medicaid enrollees (MailedFIT+forMd); Provider assessment and feedback (PAF+).

Bold indicates percent UTD ≥ 70.5% target;

^ **Bold** indicates percent UTD ≥ 80% target.

Table 3

Number of CRC cases and deaths averted among the simulated North Carolina population (N = 2,822,057 at start of intervention) by multicomponent intervention, compared to usual care, assuming that eligibility for the Medicaid program is not expanded.

Reach	Outcomes	Usual Care (referent)	Incremental change in CRC cases and deaths compared to usual care			
			Mailed FIT+	PN-for-col+	Mailed FIT+forMd	PAF+
25%	Total CRC cases	161,100	− 3085 (− 10,134, 3394)	− 13,792 (− 21,140, − 7536)	− 87 (− 8410, 8107)	− 843 (− 7944, 5523)
	Stage 1	34,543	+26	− 2314	− 14	+31
	Stage 2	31,845	− 379	− 2511	− 28	− 105
	Stage 3	53,079	− 1395	− 4919	− 19	− 368
	Stage 4	41,633	− 1337	− 4049	− 25	− 401
	Total CRC deaths	79,171 (76,564, 81,311)	− 1745 (− 5196, 701)	− 6068 (− 9489, − 3725)	−44 (−4206, 3243)	− 513 (− 3847, 2075)
50%	Total CRC cases	161,100	− 5893 (− 12,631, 400)	− 20,814 (−27,966, −14,637)	− 164 (− 8443, 8261)	− 1927 (− 9222, 4461)
	Stage 1	34,543	− 11	− 3521	−6	+13
	Stage 2	31,845	− 725	− 3808	− 23	− 242
	Stage 3	53,079	− 2638	− 7425	− 60	− 816
	Stage 4	41,633	− 2519	− 6061	− 76	− 882
	Total CRC deaths	79,171 (76,564, 81,311)	− 3325 (− 6820, − 917)	− 9133 (− 9489, − 3725)	− 72 (− 4158, 3154)	− 1112 (− 4640, 1417)
75%	Total CRC cases	161,100	−8318 (−14,980, − 2275)	− 24,350 (−31,362, −18,294)	− 254 (− 8535, 8186)	− 2949 (− 10,173, 3437)
	Stage 1	34,543	− 33	− 4131	− 11	− 18
	Stage 2	31,845	−1129	− 4487	− 41	− 352
	Stage 3	53,079	− 3719	− 8660	− 72	−1270
	Stage 4	41,633	− 3437	− 7071	− 130	− 1309
	Total CRC deaths	79,171 (76,564, 81,311)	− 4581 (− 8055, − 2216)	− 10,654 (− 13,980, − 8378)	− 133 (− 4297, 3047)	− 1655 (− 5129, 927)
100%	Total CRC cases	161,100	−10,289 (−16,877, −4501)	− 26,149 (−33,200, − 20,236)	− 314 (− 8487, 8200)	− 3988 (− 11,140, 2338)
	Stage 1	34,543	− 70	− 4437	− 34	− 18
	Stage 2	31,845	− 1450	− 4790	− 48	− 479
	Stage 3	53,079	− 4607	− 9324	− 93	− 1775
	Stage 4	41,633	− 4163	− 7599	− 139	− 1717
	Total CRC deaths	79,171 (76,564, 81,311)	− 5612 (− 8943, − 3223)	−11,463 (−14,872, −9229)	− 159 (− 4276, 3249)	− 2187 (− 5784, 371)

Mailed fecal immunochemical testing program (MailedFIT+); Patient navigation for screening colonoscopy (PN-for-Col+); MailedFIT+ targeted to Medicaid enrolees (MailedFIT+forMd); Provider assessment and feedback (PAF+).