Productivity Savings from Colorectal Cancer Prevention and Control Strategies

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Background: Lost productivity represents a considerable portion of the total economic burden of colorectal cancer (CRC), but cost-effectiveness studies of CRC prevention and control have not included these costs and therefore underestimate potential savings from CRC prevention and control.

Purpose: To use microsimulation modeling study to estimate and project productivity costs of CRC and to model the savings from four approaches to reducing CRC incidence and mortality: risk factor reduction, improved screening, improved treatment, and a simultaneous approach where all three strategies are implemented.

Methods: A model was developed to project productivity losses from CRC using the U.S. population with CRC incidence and mortality projected through the year 2020. Outcome measures were CRC mortality, morbidity, and productivity savings.

Results: With 2005 levels in risk factors, screening, and treatment, 48,748 CRC deaths occurred in 2010, amounting to $21 billion of lost productivity. Using prevention and treatment strategies simultaneously, 3586 deaths could have been avoided in 2010, leading to a savings of $1.4 billion. Cumulatively, by 2020, simultaneous strategies that reduce risk factors and increase screening and treatment could result in 101,353 deaths avoided and $33.9 billion in savings in reduced productivity loss. Improved screening rates alone led to nearly $14.7 billion in savings between 2005 and 2020, followed by risk factor reduction ($12.4 billion) and improved treatment ($8.4 billion).

Conclusions: The savings in productivity loss from strategies to reduce CRC incidence and mortality are substantial, providing evidence that CRC prevention and control strategies are likely to be cost-saving.

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Introduction

Colorectal cancer (CRC) is the fourth most common malignancy and second most common cause of cancer death among Americans.[1] In recent years, CRC incidence and mortality rates declined, with the greatest annual decline observed between the years 2002 and 2004.[2] These declines are associated with increased screening, earlier-stage diagnosis, and improvements in cancer treatment.[3–8]

Despite these encouraging trends, the absolute number of newly diagnosed CRC patients and CRC deaths will increase in the coming decades because of the aging population. Rising numbers of patients with CRC and resultant deaths will inflict considerable costs to society.[9] Mariotto et al.[10] forecast that annual costs of CRC treatment and time costs will be $17.7 billion by the year 2020 if current trends in CRC continue. These costs are only a portion of the total burden of CRC as they exclude cost estimates for productivity losses. The cost of productivity loss is broadly defined as the monetary value of output (usually estimated as wages) that would have been produced in absence of illness, disability, or premature mortality. Costs attributable to productivity losses—even in elderly populations—can be considerable and, in younger populations with large labor force participation, can equal or exceed the cost of medical care.[11]

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Interventions to reduce risk factors and improve screening and treatment are effective at reducing the burden of CRC by inducing savings through avoided treatment, morbidity, and mortality costs.[12,13] Few cost studies of CRC prevention and treatment include productivity losses in their estimates, and as a result, grossly undercount potential savings. Estimates of productivity loss are not readily accessible, but are nonetheless critical when considering a societal perspective for evaluations of approaches to curb the costs associated with CRC mortality and morbidity. A model is developed that estimates productivity loss from CRC incidence and mortality from a societal perspective. Potential savings are projected from the implementation of the following approaches to CRC prevention and control: risk factor reduction, improved screening, and more widespread use of adjuvant chemotherapy.

Methods

This paper provides intervention-specific mortality information that can be used in comparative effectiveness studies of CRC prevention and control programs and assesses the value of these benefits, which can be used in cost-effectiveness and cost–benefit analyses. The model uses CRC incidence and mortality projections from sophisticated models produced by the National Cancer Institute's (NCI's) Cancer Intervention and Surveillance Modeling Network (CISNET)[14] in conjunction with economic models that incorporate the potential for savings from loss productivity from CRC morbidity and mortality. By bringing CISNET member-generated projections in CRC incidence and mortality together with economic models of productivity losses and associated savings, the model provides a realistic assessment of the potential to reduce the economic burden from CRC. Prior studies have used simplistic assumptions (e.g., a 1% annual reduction in CRC mortality) that are not attached to a strategy for prevention and control.[15,16] In this paper, estimates that can be compared across specific strategies for reducing CRC incidence and mortality are provided.

The incidence and mortality projections and associated life-years with CRC and life-years lost to CRC are based on a simulation of the U.S. population from birth to death with MISCAN-Colon, a semi-Markov microsimulation model from the NCI's CISNET.[14] The MISCAN-Colon model generates durations for each person in each state, assuming an exponential distribution of the duration in each state. States in the MISCAN model can be continuous as opposed to discrete. The Monte Carlo method is used to simulate birth and death of a person, adenoma incidence, and transitions from one state of disease to another.[12]

CRC occurs in this population according to the adenoma–carcinoma sequence.[17,18] Adenomas can progress in size from small (1–5 mm) to medium (6–9 mm) to large (≥10 mm). More than one adenoma can occur in an individual and although most adenomas never develop into cancer, some transform to a Stage I cancer. The cancer may then progress from Stage I to Stage IV. In every stage, there is a chance of cancer diagnosis and survival that depends on a person's age, gender, and race and on cancer stage and localization (colon versus rectum).[12]

The MISCAN-Colon model is calibrated to reproduce the 1975–1979 age-specific CRC incidence rates by gender, representative of the U.S. population prior to CRC screening. The life tables were derived from the 2000 U.S. Life Table published by the National Center for Health Statistics (http://www.cdc.gov/nchs/products/pubs/pubd/lftbls/life/1966.htm). Life-years lost are estimated as age at death from other causes minus age at death from CRC. Subsequently, trends in risk factor prevalence and screening and treatment are added to the model from 1975 to 2005 to generate a population with the characteristics of the white and African-American U.S. population in 2005. Other racial and ethnic groups were not included because comparable data are not available for them. Risk factors include smoking, obesity, and red meat consumption as well as the protective factors of aspirin and/or nonsteroidal anti-inflammatory use, multivitamin use, physical activity, fruit and vegetables intake, and hormone replacement therapy.

Screening modalities include fecal occult blood tests and endoscopy (including separate estimates for flexible sigmoidoscopy and colonoscopy). The National Health Interview Survey (NHIS)[19] provides rates for ever being screened and time since last screening by 5-year age groups in 1987, 1992, 1998, 2000, 2003, and 2005. The use and efficacy of four adjuvant chemotherapy regimens considered are 5-fluorouracil alone; 5-fluorouracil and irinotecan; 5-fluorouracil, irinotecan, and oxaliplatin; and 5-fluorouracil, irinotecan, oxaliplatin, and bevacizumab/cetuximab. The efficacy of each treatment regimen is estimated from hazard ratios from published clinical trials[20–31] that are then applied to the 1975 through 1979 stage-specific relative survival rates from Surveillance Epidemiology and End Results. The model inputs and extrapolations are explained in further detail in Appendix A (available online at www.ajpmonline.org) and in other published studies.[4,32]

Prevention and Control Strategies

The CRC simulation model estimates the impact of the following cancer prevention and treatment strategies from 2005 through 2020 relative to a stabilization of 2005 levels in risk factors, screening rates, and adjuvant chemotherapy use with the U.S. population growing and aging at the projected rate:

1. Risk factor reduction: Risk factors are reduced in the population, but screening and treatment trends remain at the 2005 levels.
2. Screening rates increase: Screening rates are increased in the population, but risk factors and chemotherapy stay at the 2005 levels.
3. Chemotherapy use increases: Adjuvant chemotherapy use is increased, but risk factors and screening stay at the 2005 level.
4. Simultaneous interventions: Risk factors are reduced and screening and adjuvant chemotherapy use increases. The model assumes a synergistic effect among strategies that resulted in a different number of deaths than would be achieved had each strategy been implemented individually.

Table 1 reports the risk factor, screening, and treatment rates used in the model for 2005, 2010, and 2020. Projected rates for prevention and control strategies are optimistic but considered to be realistic based on observed trends. Estimated mortality benefits from the MISCAN model are aggregated by adult men and women in 5-year age groups.

Table 1. Risk factors, screening, and treatment assumptions using continuation of 2005 levels and optimistic levels for 2010 and 2020

Risk factor	2005 levels (%)	2010 optimistic assumptions (%)	2020 optimistic assumptions (%)
Current smokers			
White, male	21	8	4
White, female	18	8	7
Black, male	29	15	10
Black, female	18	8	9
Obese			
White, male	31	30	27
White, female	38	41	45
Black, male	30	29	30
Black, female	56	58	57
Moderate or vigorous physical activity			
White, male	33	35	42
White, female	30	33	40
Black, male	37	38	38
Black, female	28	32	35
Eating five or more servings of fruits/ vegetables per day			
White, male	44	47	51
White, female	36	39	45
Black, male	37	41	48
Black, female	34	37	38
Using multivitamins			
White, male	49	62	75
White, female	48	58	68
Black, male	24	30	38
Black, female	30	37	36
Receiving hormone replacement therapy[a]			
White, female	10	9	9
Black, female	3	3	3
Eating two or more servings/week of red meat			
White, male	30	29	26
White, female	23	21	16
Black, male	32	32	32
Black, female	24	21	17
Aspirin/NSAID users[a]			
White, male	45	50	56

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Productivity Loss from Premature Mortality

The human capital method is used to estimate employment and gross earnings transitions over the life cycle by summing the expected earnings in each year of forgone life over a given life expectancy. The model reflects employment and income transitions over the life cycle by summing the expected earnings in each year of forgone life over a given life expectancy, accounting for changes in the probability of employment and wages that occur from year to year and from age group to age group. An imputed value of informal caregiving and household activities is included. These are services in which CRC patients are engaged in addition to paid work; they are not services provided on behalf of CRC patients.

The present value of gross lifetime earnings as the sum of productivity costs and the sum of the imputed value of caregiving and household activities are estimated. All estimates of wages, employment rates, and full- and part-time employment rates are from the Current Population Survey, which is the primary source of information on labor force characteristics and behavior of the U.S. population.[33] Wages are estimated for 5-year age groups (starting with age 20 years), but are combined for all ages ≥70 years. Full-time and part-time annual earnings are upwardly adjusted by 22.4% and 10.3%, respectively, to reflect the value of health insurance and retirement benefits, which are considered part of total compensation.[34] To estimate wages for future years, wages are adjusted for each year beyond 2006 for inflation using the Consumer Price Index.[35]

Responses to the National Human Activity Pattern Survey, which collects informa-

tion on household production and providing care, are used to estimate the number of CRC patients engaged in caregiving and housekeeping.[34] The methods used to impute a wage rate for these individuals are explained in Bradley et al.[15] and in Appendix A (available online at www.ajpmonline.org). All cost streams are in real terms and reported in 2006 dollars. A discount rate of 3% is applied to productivity estimates to convert future dollars into their present value.

Morbidity Costs

The NHIS collects data on respondents' inability to work due to health limitations and work loss days in the past 12 months. The difference between the percentage of NHIS respondents (years 1997–2007) with CRC and those without cancer by age and gender who report they cannot work because of a disability is used to estimate productivity loss attributable to CRC. Similarly, the difference in work hours lost due to a health condition is estimated between those with and without CRC and multiplied by CRC prevalence for each age and gender group by the percentage of CRC-attributable non-employment and work hours loss to surviving CRC patients. The cost of productivity loss due to morbidity is estimated using employment rates, wage estimates, and a discount rate as described in the preceding section. The MISCAN's intervention-specific projections of incidence and mortality reductions are applied to the cost of CRC mortality and morbidity productivity losses by gender and 5-year age group.

Results

Colorectal Cancer Deaths

The expected numbers of CRC deaths by gender for

Table 1. Risk factors, screening, and treatment assumptions using continuation of 2005 levels and optimistic levels for 2010 and 2020 *(continued)*

Risk factor	2005 levels (%)	2010 optimistic assumptions (%)	2020 optimistic assumptions (%)
White, female	46	49	53
Black, male	19	19	19
Black, female	24	22	20
SCREENING BEHAVIOR			
Aged >50 years have had FOBT within past 2 years			
White, male	24	22	23
White, female	25	23	25
Black, male	20	22	23
Black, female	23	24	26
Aged >50 years, have had a sigmoidoscopy or colonoscopy at some point in their lives[a]			
White, male	54	63	70
White, female	49	59	69
Black, male	44	50	59
Black, female	43	55	64
ADJUVANT CHEMOTHERAPY USE BY STAGE			
Stage II cancer			
Not receiving chemotherapy			
Whites	51	47	47
Blacks	59	47	47
Receiving 5FU			
Whites	20	0	0
Blacks	16	0	0
Receiving FOLFOX			
Whites	29	53	53
Blacks	25	53	53
Stage III cancer			
Not receiving chemotherapy			
Whites	24	19	19
Blacks	36	19	19
Receiving 5FU			
Whites	28	0	0
Blacks	23	0	0
Receiving FOLFOX			
Whites	48	81	81
Blacks	41	81	81

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Table 1. *(continued)*

Risk factor	2005 levels (%)	2010 optimistic assumptions (%)	2020 optimistic assumptions (%)
Stage IV cancer			
Not receiving chemotherapy			
Whites	30	23	23
Blacks	41	23	23
Receiving 5FU			
Whites	5	0	0
Blacks	4	0	0
Receiving 5FU + irinotecan			
Whites	1	0	0
Blacks	1	0	0
Receiving FOLFOX			
Whites	13	0	0
Blacks	11	0	0
Receiving FOLFOX + antibodies			
Whites	50	77	77
Blacks	43	77	77

Note: Risk factor prevalence is based on data from four waves of the National Health and Nutrition Examination Surveys (1971–1975, 1976–1980, 1988–1994, and 1999–2002). Screening dissemination is based on data from the National Health Interview Survey in 1987, 1992, 1998, and 2000. Use of adjuvant chemotherapy is estimated from the published literature.[20–31]

[a]Value is the projected trend level. An optimistic goal was not used because the risks from hormone replacement therapy and aspirin/NSAID use may outweigh the benefits.

FOBT, fecal occult blood test; FOLFOX, folinic acid (leucovorin), fluorouracil, and oxaliplatin; FU, fluorouracil; NSAID, nonsteroidal anti-inflammatory drug

each strategy is estimated for each year from 2005 through 2020 and are reported for the year 2010 and cumulatively for 2005 through 2020 (Table 2). Assuming that CRC screening, treatment, and risk factor levels from 2005 continued through 2010, there will be 48,748 deaths from CRC in 2010; further, 23,783 deaths will be in women and 24,965 deaths will be in men. If all interventions had been implemented simultaneously in 2005, there would have been 3586 fewer deaths in 2010. Improved screening rates and improved adjuvant chemotherapy use provide the greatest contribution to the number of deaths avoided in 2010 (2074 and 1316, respectively). A strategy focusing on risk factor reduction has small gains in deaths avoided in 2010 (n=295) because its benefits are minimal in the short run and can be fully realized only after several decades. Cumulatively, the number of deaths avoided between 2005 and 2020 by strategy is 19,158 (risk factor reduction); 65,692 (screening rates increase); 21,591 (adjuvant chemotherapy use increase); and 101,353 (simultaneous strategies).

Estimated Cost of Productivity Loss

In 2010, the productivity loss from CRC morbidity and mortality is estimated to be $20.9 billion if 2005 levels in risk factors, screening rates, and adjuvant chemotherapy use persists (upper panel, Table 3). The greatest share of the cost is from premature mortality and only about 3% is due to productivity loss from morbidity. In 2020, the savings increase by nearly fourfold. The implementation of simultaneous interventions in 2005 would have resulted in a savings of $4.2 billion relative to the stabilization and continuation of 2005 levels.

Cumulative costs provide insight into how costs and potential savings can add up over time. Between 2010 and 2020, productivity costs accumulate to $339 billion if 2005 levels in risk factors, screening rates, and adjuvant chemotherapy use persist (lower panel, Table 3). The simultaneous approach to CRC prevention and control results in the lowest productivity loss ($122 billion and $305 billion in 2010 and 2020, respectively). In 2020, this represents a cumulative savings of $33.5 billion. When considering individual strategies, in 2020, the cumulative cost of productivity loss attributable to CRC decreases to $325 billion with improved screening, $327 with reduced risk factors, and $331 with increased use of adjuvant chemotherapy. Figure 1 demonstrates the potential cumulative savings from the implementation of each strategy and a simultaneous implementation of all three strategies.

Discussion

Without interventions to reduce the incidence and mortality of CRC, the projected cumulative productivity cost of CRC from 2005 through 2020 is projected to be $339 billion. Other published studies report that the cost of CRC care, which focuses on medical costs, is projected to

be more than $14 billion in 2010. These costs are projected to exceed $17 billion by 2020.[10] Added to the annual productivity costs estimated, the total economic burden of CRC would be $39 billion in 2020. With simultaneous risk factor reduction and improvements in screening and treatment, estimated reductions in productivity loss alone are projected to be $4.2 billion in 2020, amounting to $33.5 billion cumulatively from 2010 to 2020.

Among the CRC prevention and treatment strategies, increased screening offers the greatest savings because it avoids the greatest number of deaths from CRC. A policymaker faced with having to choose to concentrate resources to improve current trends in CRC prevention and treatment would most likely choose to improve screening rates, depending on the relative costs to implement the intervention. The strategy with the next greatest savings is risk factor reduction. Over time, it is expected that benefits from this strategy will increase. Risk factor modification has the additional benefit of reducing CRC and other-cause mortality. Increased adjuvant chemotherapy use offered immediate savings but did not reduce the total number of CRC patients.

Table 2. Deaths avoided by strategy (2010) and cumulative deaths avoided 2005–2020

	Deaths 2010	Deaths avoided relative to 2005 levels, 2010	Cumulative deaths avoided, 2005–2020
Stabilization and continuation of 2005 levels in risk factors, screening, and chemotherapy			
Women	23,783	N/A	N/A
Men	24,965	N/A	N/A
Total	48,748	N/A	N/A
STRATEGY			
Simultaneous interventions[a]			
Women	21,972	1811	50,753
Men	23,190	1775	50,600
Total	45,162	3586	101,353
Risk factors improve			
Women	23,623	160	8,364
Men	24,830	135	10,793
Total	48,453	295	19,158
Screening rates increase			
Women	22,800	983	33,864
Men	23,874	1091	31,828
Total	46,674	2074	65,692
Chemotherapy use increases			
Women	23,196	587	10,205
Men	24,236	729	11,386
Total	47,432	1316	21,591

[a]The simulation of the benefits from the implementation of simultaneous interventions allows for a synergistic effect among strategies that results in a different number of deaths than would be achieved with each strategy implemented individually.
N/A, not applicable

Costs associated with risk factor reduction and improved screening and treatment are required to fully assess the cost effectiveness or comparative effectiveness of CRC prevention and treatment programs. Published studies have estimated the costs of a screening test to range from $4.54 for hemoccult II to $846 for colonoscopy with polypectomy or biopsy.[12] The cost-to-treat screening complications range from $320 to $12,446 depending on the complication type and severity.[12] Using these estimates, screening programs are likely to have a favorable cost-effectiveness ratio when reductions in productivity loss are included in the analysis. Increased adjuvant chemotherapy treatment may have a less favorable cost-effectiveness ratio. Combinations of 5-FU and oxaliplatin can cost approximately $2500 per cycle[12] and six cycles of bevacizumab can add $60,000 to treatment costs.[36] Nevertheless, increased use of these therapies can be beneficial.

The current research combines estimates of productivity costs with sophisticated projections of incidence and mortality as a function of future trends in CRC risk factors, screening, and treatment and contributes to litera-

Table 3. Annual and cumulative productivity losses by strategy relative to 2005 levels in risk factors, screening rates, and adjuvant chemotherapy use

	2010 ($, billions)			2020 ($, billions)		
Annual productivity losses	**Morbidity**	**Mortality**	**Total**	**Morbidity**	**Mortality**	**Total**
Stabilization and continuation of 2005 levels in risk factors, screening, and chemotherapy						
Women	0.28	8.57	8.85	0.37	8.92	9.30
Men	0.44	11.64	12.08	0.58	11.90	12.48
Total	0.71	20.21	20.92	0.96	20.83	21.78
STRATEGY						
Simultaneous interventions[a]						
Women	0.28	7.95	8.22	0.34	7.17	7.52
Men	0.44	10.90	11.33	0.53	9.52	10.05
Total	0.71	18.85	19.56	0.87	16.69	17.57
Risk factors improve						
Women	0.28	8.44	8.72	0.35	8.22	8.57
Men	0.43	11.48	11.91	0.53	10.62	11.15
Total	0.71	19.92	20.63	0.88	18.83	19.72
Screening rates increase						
Women	0.28	8.31	8.59	0.37	8.08	8.45
Men	0.44	11.30	11.73	0.57	11.06	11.63
Total	0.72	19.60	20.32	0.94	19.14	20.08
Chemotherapy use increases						
Women	0.28	8.33	8.61	0.38	8.64	9.02
Men	0.44	11.32	11.76	0.59	11.51	12.10
Total	0.72	19.66	20.37	0.97	20.15	21.12
	2005 through 2010 ($, billions)			**2005 through 2020 ($,billions)**		
Cumulative productivity losses	**Morbidity**	**Mortality**	**Total**	**Morbidity**	**Mortality**	**Total**
Stabilization and continuation of 2005 levels in risk factors, screening, and chemotherapy						
Women	1.54	52.18	53.71	4.85	139.67	144.53
Men	2.40	70.15	72.55	7.58	187.12	194.70
Total	3.94	122.33	126.26	12.43	326.79	339.22
STRATEGY						
Simultaneous interventions[a]						
Women	1.54	50.07	51.61	4.72	124.85	129.57
Men	2.41	67.62	70.04	7.35	168.42	175.77
Total	3.95	117.69	121.65	12.06	293.28	305.34
Risk factors improve						
Women	1.53	51.82	53.35	4.72	134.95	139.67

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Table 3. Annual and cumulative productivity losses by strategy relative to 2005 levels in risk factors, screening rates, and adjuvant chemotherapy use *(continued)*

	2005 through 2010 ($, billions)			2005 through 2020 ($,billions)		
Cumulative productivity losses	**Morbidity**	**Mortality**	**Total**	**Morbidity**	**Mortality**	**Total**
Men	2.39	69.79	72.18	7.33	179.82	187.15
Total	3.92	121.61	125.53	12.05	314.77	326.82
Screening rates increase						
Women	1.54	51.48	53.02	4.82	132.80	137.62
Men	2.41	69.20	71.61	7.53	179.37	186.90
Total	3.95	120.68	124.64	12.35	312.17	324.52
Chemotherapy use increases						
Women	1.54	51.15	52.70	4.89	135.98	140.87
Men	2.41	68.84	71.24	7.63	182.32	189.95
Total	3.95	119.99	123.94	12.52	318.30	330.82

[a]The simulation of the benefits from the implementation of simultaneous interventions allows for a synergistic effect among strategies that results in a different number of deaths than would be achieved with each strategy implemented individually.

ture in two important ways. First, the model provides population-based estimates of one of the largest costs—productivity loss—from CRC. Second, the model provides evidence that can contribute to studies of the comparative effectiveness of CRC prevention and treatment approaches relative to allowing 2005 levels in incidence and mortality to continue. Costs associated with productivity loss should be considered in conjunction with CRC treatment costs. Given that treatment costs continue to rise with the introduction of expensive therapies such as oxaliplatin, irinotecan, and bevacizumab,[12] strategies that avoid the need for these therapies are likely to be preferred.

Several limitations are noteworthy. First, life expectancy estimates include CRC, so the years of life lost estimates may be understated because in absence of CRC, life expectancy would be longer. Second, the benefit of risk factor reduction is estimated as a reduction in incidence, but recent studies have shown that reducing risk factors can also improve survival for CRC patients.[37–39] Therefore, the savings from risk factor reduction will be more favorable when survival benefits for patients are added to the model. Third, not all risk factors (e.g., alcohol consumption) are included in the simulation. However, the exclusion of risk factors such as alcohol consumption is not likely to affect the outcomes of the simulation.[40]

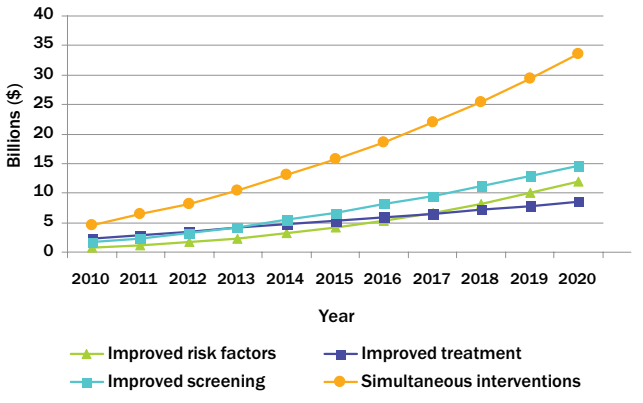

Figure 1. Cumulative projected total productivity loss savings from colorectal cancer prevention and control strategies, 2010 through 2020

Fourth, the MISCAN model does not estimate CIs around mortality and incidence point estimates. Fifth, the estimates are at the population level and do not account for individual variability in employment, wages, and absenteeism. Sixth, no consideration was given to improvements in survival that could be achieved through improved surgical techniques and radiation. Finally, CRC patient caregivers' productivity loss during the time they transport and care for CRC patients is not estimated. Expanding the scope of the model to include productivity losses from patients' caregivers would increase the total savings gained from each approach to CRC prevention and control. Likewise, the value of CRC patients' time to participate in screening and treatment and possibly risk factor reduction (e.g., participating in exercise activities, smoking-cessation counseling) would add to the costs of these interventions and reduce net benefits.

Estimates provided in this paper can inform future studies of cost effectiveness and comparative effective-

ness of strategies aimed toward reducing the burden of CRC. The evidence suggests that investments in strategies to reduce CRC incidence and mortality are likely to be cost-saving and the potential for savings from avoided productivity loss is substantial—even in a population of older individuals. The estimates in this study favor strategies such as screening and risk factor reduction that either reduces the number of CRC cases or alters the course of disease. In light of the considerable cost of productivity loss and rising treatment costs, the strategies presented offer economical approaches for reducing the burden of CRC.

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References

1. Jemal A, Siegel R, Xu J, Ward E. Cancer statistics, 2010. CA Cancer J Clin 2010;60(5):277–300.
2. Epsey DK, Wu XC, Swan J, et al. Annual report to the nation on the status of cancer, 1975–2004, featuring cancer in American Indians and Alaska Natives. Cancer 2007;110(10):2119–52.
3. Swan J, Breen N, Coates RJ, Rimer BK, Lee NC. Progress in cancer screening practices in the U.S.: results from the 2000 National Health Interview Survey. Cancer 2003;97(6):1528–40.
4. Vogelaar I, van Ballegooijen M, Schrag D, et al. How much can current interventions reduce colorectal cancer mortality in the U.S.? Mortality projections for scenarios of risk-factor modification, screening, and treatment. Cancer 2006;107(7):1624–33.
5. Gross CP, Andersen MS, Krumholz HM, McAvay GJ, Proctor D, Tinetti ME. Relation between Medicare screening reimbursement and stage at diagnosis for older patients with colon cancer. JAMA 2006;296(23):2815–22.
6. Mandel JS, Bond JH, Church TR, et al. Reducing mortality from colorectal cancer by screening for fecal occult blood. Minnesota Colon Cancer Control Study. N Engl J Med 1993;328(19):1365–71.
7. Edwards BK, Brown ML, Wingo PA, et al. Annual report to the nation on the status of cancer, 1975–2002, featuring population-based trends in cancer treatment. J Natl Cancer Inst 2005;97(19):1407–27.
8. Potosky AL, Harlan LC, Kaplan RS, Johnson KA, Lynch CF. Age, sex, and racial differences in the use of standard adjuvant therapy for colorectal cancer. J Clin Oncol 2002;20(5):1192–202.
9. Mariotto A, Warren JL, Knopf KB, Feuer EJ. The prevalence of patients with colorectal carcinoma under care in the U.S. Cancer 2003;98(6):1253–61.
10. Mariotto AB, Yabroff KR, Shao Y, Feuer EJ, Brown ML. Projections of the cost of cancer care in the U.S.: 2010–2020. J Natl Cancer Inst 2011;103:1–12.
11. National Cancer Institute. National Cancer Institute 2006 Fact Book. 2007. obf.cancer.gov/financial/attachments/06Factbk.pdf.
12. Vogelaar I, van Ballegooijen M, Zauber AG, Habbema JD, Kuipers EJ. Effect of rising chemotherapy costs on the cost savings of colorectal cancer screening. J Natl Cancer Inst 2009;101(20):1412–22.
13. Pignone M, Saha S, Hoerger T, Mandelblatt J. Cost-effectiveness analyses of colorectal cancer screening: a systematic review for the U.S. Preventive Services Task Force. Ann Intern Med 2002;137(2):96–104.
14. National Cancer Institute's Cancer Intervention and Surveillance Modeling Network. National Cancer Institute website. cisnet.cancer.gov.
15. Bradley CJ, Yabroff KR, Dahman B, Feuer EJ, Mariotto A, Brown ML. Productivity costs of cancer mortality in the U.S.: 2000–2020. J Natl Cancer Inst 2008;100(24):1763–70.
16. Yabroff KR, Bradley CJ, Mariotto AB, Brown ML, Feuer EJ. Estimates and projections of value of life lost from cancer deaths in the U.S. J Natl Cancer Inst 2008;100(24):1755–62.
17. Morson B. President's address. The polyp-cancer sequence in the large bowel. Proc R Soc Med 1974;67(6):451–7.
18. Muto T, Bussey HJ, Morson BC. The evolution of cancer of the colon and rectum. Cancer 1975;36(6):2251–70.
19. National Health Interview Survey. CDC website. www.cdc.gov/nchs/nhis.htm.
20. André T, Boni C, Mounedji-Boudiaf L, et al.; Multicenter International Study of Oxaliplatin/5-Fluorouracil/Leucovorin in the Adjuvant Treatment of Colon Cancer (MOSAIC) Investigators. Oxaliplatin, fluorouracil, and leucovorin as adjuvant treatment for colon cancer. N Engl J Med 2004;350(23):2343–51.
21. International Multicentre Pooled Analysis of Colon Cancer Trials (IMPACT) Investigators. Efficacy of adjuvant fluorouracil and folinic acid in colon cancer. Lancet 1995;345(8955):939–44.
22. International Multicentre Pooled Analysis of B2 Colon Cancer Trials (IMPACT B2) Investigators. Efficacy of adjuvant fluorouracil and folinic acid in B2 colon cancer. J Clin Oncol 1999;17(5):1356–63.
23. Gill S, Loprinzi CL, Sargent DJ, et al. Pooled analysis of fluorouracil-based adjuvant therapy for stage II and III colon cancer: who benefits and by how much? J Clin Oncol 2004;22(10):1797–806.
24. Hurwitz H, Fehrenbacher L, Novotny W, et al. Bevacizumab plus irinotecan, fluorouracil, and leucovorin for metastatic colorectal cancer. N Engl J Med 2004;350(23):2335–42.
25. Moertel CG, Fleming TR, Macdonald JS, et al. Intergroup study of fluorouracil plus levamisole as adjuvant therapy for stage II/Dukes' B2 colon cancer. J Clin Oncol 1995;13(12):2936–43.
26. Moertel CG, Fleming TR, Macdonald JS, et al. Fluorouracil plus levamisole as effective adjuvant therapy after resection of stage III colon carcinoma: a final report. Ann Intern Med 1995;122(5):321–6.
27. Cunningham D, Humblet Y, Siena S, et al. Cetuximab monotherapy and cetuximab plus irinotecan in irinotecan-refractory metastatic colorectal cancer. N Engl J Med 2004;351(4):337–45.
28. Saltz LB, Cox JV, Blanke C, et al. Irinotecan plus fluorouracil and leucovorin for metastatic colorectal cancer. Irinotecan Study Group. N Engl J Med 2000;343(13):905–14.
29. Saltz L, Niedzwiecki D, Hollis D, et al. Irinotecan fluorouracil plus leucovorin is not superior to fluorouracil plus leucovorin alone as adjuvant treatment for stage III colon cancer: results of CALGB 89803. J Clin Oncol 2007;25(23):3456–61.
30. de Gramont A, Figer A, Seymour M, et al. Leucovorin and fluorouracil with or without oxaliplatin as first-line treatment in advanced colorectal cancer. J Clin Oncol 2000;18(16):2938–47.
31. Goldberg RM, Sargent DJ, Morton RF, et al. A randomized controlled trial of fluorouracil plus leucovorin, irinotecan, and oxaliplatin combinations in patients with previously untreated metastatic colorectal cancer. J Clin Oncol 2004;22(1):23–30.
32. Colorectal Cancer and Mortality Projections. National Cancer Institute. cisnet.cancer.gov/projections/colorectal.
33. U.S. Department of Labor, Bureau of Statistics and U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau. Current Population Survey, Design and Methodology, Technical Paper CPS TP63, Washington DC. www.bls.census.gov/cps/tp/tp63.htm.
34. Grosse S. Appendix I: productivity loss tables. In: Haddix AC, Teutsch SM, Corso PS, eds. Prevention effectiveness: a guide to decision analy-

sis and economic evaluation. 2nd ed. New York NY: Oxford University Press, 2003:255–7.
35. Consumer Price Index. U.S. Department of Labor Bureau of Statistics website. stats.bls.gov/cpi/home.htm#data.
36. Schrag D. The price tag on progress—chemotherapy for colorectal cancer. N Engl J Med 2004;351(4):317–9.
37. Demark-Wahnefried W. Cancer survival: time to get moving? Data accumulate suggesting a link between physical activity and cancer survival. J Clin Oncol 2006;24(22):3517–8.
38. Coghill AE, Newcomb PA, Campbell PT, et al. Prediagnostic non-steroidal anti-inflammatory drug use and survival after diagnosis of colorectal cancer. Gut 2011;60(4):491–8.
39. Vrieling A, Kampman E. The role of body mass index, physical activity, and diet in colorectal cancer recurrence and survival: a review of the literature. Am J Clin Nutr 2010;92(3):471–90.
40. Cho E, Smith-Warner SA, Ritz J, et al. Alcohol intake and colorectal cancer: a pooled analysis of 8 cohort studies. Ann Intern Med 2004;140(8):603–13.