Estimated Economic Burden of Cancer Associated with Suboptimal Diet in the United States

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Abstract

Purpose: Suboptimal diet is a preventable cause of cancer. We aimed to estimate the economic burden of diet-associated cancer among US adults.

Methods: We used a Comparative Risk Assessment model to quantify the number of new cancer cases attributable to seven dietary factors among US adults ages 20+ years. A Markov cohort model estimated the 5-year medical costs for 15 diet-associated cancers diagnosed in 2015. We obtained dietary intake from 2013-2016 National Health and Nutrition Examination Survey, cancer incidence and survival from 2008-2014 Surveillance, Epidemiology, and End Results (SEER) program, and medical costs from 2007-2013 linked SEER-Medicare data.

Results: The estimated 5-year medical costs of new diet-associated cancer cases diagnosed in 2015 were $7.44 (2018 US$). Colorectal cancer had the largest diet-related 5-year medical costs of $5.32B. Suboptimal consumption of whole grains ($2.76B), dairy ($1.82B) and high consumption of processed meats ($1.5B) accounted for the highest medical costs. Per-person medical costs attributable to suboptimal diet vary by gender, race and age group.

Conclusions: Suboptimal diet contributes substantially to the economic burden of diet-associated cancers among US adults. This study highlights the need to implement population-based strategies to improve diet and reduce cancer burden in the US.

Introduction

The economic burden of cancer has increased substantially over the past two decades despite an overall decline in age-adjusted cancer incidence [1]. It has been estimated that the annual direct medical costs of cancer care will reach $158 billion in the United States (US) in 2020 [2]. These rapidly rising expenditures underline the importance of novel strategies to advance cancer prevention and reduce costs. To date, assessments of health and economic impact of cancer prevention strategies have focused largely on early detection strategies such as screening or tertiary prevention strategies such as chemotherapy or post-diagnosis interventions [3]. Fewer efforts have been directed to primary prevention such as dietary interventions for cancer prevention [3]. Poor diet is among the top risk factors for disease burden in the US [4] and is a major preventable cause of cancer [5]. An estimated 80,110 new cancer cases annually have been attributable to suboptimal diet, accounting for 5.2% of all newly diagnosed cancers among US adults [6]. The associated economic burden may be substantial; however, it has not been quantified. An understanding of the economic burden of cancer attributable to poor diet, including costs associated with specific dietary factors and cancer types, and stratified by age, sex and race is important to inform targeted evidence-based interventions to reduce cancer burden and costs in the US.

Zhang et al. (2019) identified seven dietary factors having strong evidence for etiologic effects on cancer risk based on the strength of the evidence graded by the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) (low intake of fruits, vegetables, whole grains, and dairy, and high intake of processed meats and red meats) or having a causal impact mediated through obesity (sugar-sweetened beverages) [6]. In this study, we aimed to quantify the 5-year medical costs of 15 cancers, attributable to the seven dietary factors, among US adults diagnosed in 2015. We further evaluated disparities in diet-associated economic burden by age, sex, and race.

Methods

Study Design

We applied a comparative risk assessment (CRA) modeling framework [6] to quantify the population attributable fraction (PAF) of new cancer cases attributable to 7 dietary factors among US adults in 2015. The CRA model incorporated data and corresponding uncertainty on (1) dietary intake among US adults by age, sex, and race; (2) relative risk estimates for diet and cancer risk; (3) relative risk estimates for body mass index (BMI) and cancer risk; (4) effect estimates of change in diet with change in BMI; (5) optimal intake distributions of these dietary factors; and (6) cancer incidence in 2015 by age, sex, and race [6]. The PAFs and corresponding uncertainty derived from the CRA model were incorporated into a Markov cohort model to estimate the 5-year medical costs of new cancer cases attributable to suboptimal diet in 2015. The Markov cohort model also incorporated data and corresponding uncertainty on (7) phase-specific medical costs of 15 cancers and (8) mortality due to cancer and other causes. All data inputs are presented in **eTable1**.

Current and Optimal Distributions of Dietary Intake

The current distributions of the seven dietary factors were estimated using a nationally representative sample of US adults from the two most recent cycles of the National Health and Nutrition Examination Survey (NHANES) (2013-2014 and 2015-2016) [7]. We applied the National Cancer Institute (NCI) method to correct for within vs. between-variation associated with 24-hour diet recalls to estimate usual intakes. The optimal distribution of these dietary factors – the level of intake with evidence to produce the lowest disease risk – was derived from the Global Burden of Disease (GBD) 2010 [8].

Etiologic Relationship between Diet and Cancer

Similar to Zhang et al. (2019) [6], the relative risk (RR) estimates for direct (non-BMI mediated) diet-cancer relations were obtained from meta-analysis of prospective cohort studies conducted by the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) [9]. When RR estimates were not directly available from the WCRF/AICR reports for some cancers (mouth, pharynx, and larynx cancers) or dietary target (sugar-sweetened beverages), we used estimates from more recent individual meta-analysis [6]. Because these cancer risks were based on meta-analysis of studies that adjusted for BMI, we separately estimated the potential additional diet-associated cancer burden mediated through obesity. Effects of each of the dietary factors on long-term BMI change were derived from a pooled analysis among 120,997 US men and women in three prospective cohort studies [10]; and the association of BMI with 13 cancers based on meta-analyses by WCRF/AICR [6, 9] and the International Agency for Research on Cancer (IARC) [11].

Cancer Incidence, Death, and Projection

We obtained the 2015 cancer incidence from the NCI's Surveillance, Epidemiology, and End Results (SEER) 18 program [12]. Incidence for individual cancer types was obtained based on the International Classification for Diseases for Oncology Third Edition (ICD-O3) codes corresponding to the primary cancer site [13]. Conditional probability of death due to cancer or other causes over a period of 5 years (2009-2014) among individuals diagnosed with cancer were obtained from SEER 18.

Medical Costs of Cancer Care

Medical costs of cancer care for individuals age 65+ years were obtained using the SEER linked to Medicare claims data for individuals diagnosed with cancer from 2007 to 2013 [14]. Medical costs were stratified into three phases of cancer care: initial (first 12 months following diagnosis), continuing (includes all the months in-between), and last year of life (final 12 months) [15-17]. For individuals age <65 years, we estimated the costs as done in prior studies [2, 18] by applying ratios of 1.2, 1.0, and 1.5 for the initial, continuing, and last year of life phases, respectively, to the corresponding costs for individuals age 65+ years. We conservatively used a payer perspective, only including direct medical costs paid by the payer and excluding any direct or indirect medical costs incurred by the patient or societal costs due to lost productivity. All costs were adjusted to 2018 US dollars, with all future costs discounted at 3%.

Statistical Analyses

We estimated the PAF for each diet-cancer relationship using the CRA (eMethod1). For cancer with more than one associated dietary factor, joint PAFs were computed using the proportional multiplication formula for cumulative effects, which avoids overestimation that occurs with simple summation [6, 19, 20]. For each cancer type, the number of new cancer cases attributable to poor diet was estimated by multiplying the PAF by the total number of new cancers in that year. CRA analyses were performed using R statistical software, version 3.4.1.

We then used a Markov cohort model to estimate the 5-year medical costs of diet-associated cancer burdens (eMethod2). In this stochastic model, a cohort of patients newly diagnosed with a cancer attributable to suboptimal diet transition among different health states (alive or dead) during each monthly model cycle. The Markov model analyses were conducted using TreeAge Pro 2018. Uncertainties in parameters were quantified using 1000 multiway probabilistic Monte Carlo simulations.

Results

In 2015, an estimated 84,459 (95% UI = 69,766- 98,947) new cancer cases among US adults were associated with suboptimal intake of the 7 dietary factors (**Table 2**). The estimated number of new cancer cases differs to a certain extent from a previous estimate presented by Zhang et al. (2019) due to differences in racial/ethnic composition of the subgroups and modelling methods. Due to lack of availability of cancer cost estimates for Hispanics, this study has only three racial groups-white, black, and other whereas the Zhang et al. (2019) study included Hispanics as a separate group. Total 5-year direct medical costs for each cancer site by strata are presented in **eTable2**.

The estimated 5-year medical costs of the diet-attributable new cancer cases in 2015 was $7.44 billion in 2018 US$ (95% Uncertainty Intervals [UI]: $5.79-$9.27B) (Table 2). This represented 11.58% of the total 5-year medical costs for all 15 diet-associated cancers diagnosed in 2015 ($61.44B). Of this cost, $6.83 billion ($5.27-$8.52B) was attributable to direct (non-BMI mediated) associations of suboptimal diet with cancer risk, and $0.64 billion ($0.47-$0.84B) to BMI-mediated associations.

By cancer type, estimated diet-attributable costs were highest for cancers of the digestive tract including colorectal cancer ($5.32B, 95% UI:$4.42-$6.22B) and cancer of the mouth and pharynx ($1.09B, $0.7-$1.54B), larynx ($0.26B, $0.17-$0.37B), and stomach ($0.21B, $0.07-$0.43B) (Table 2). Among dietary factors, insufficient whole grain intake accounted for the largest medical costs of diet-associated cancers ($2.76B, $1.89-$4.96B), followed by insufficient dairy intake ($1.82B, $1.34-$2.36B), high consumption of processed meat ($1.5B, $0.77-$2.48B), and insufficient consumption of vegetables ($1.09B, $0.59-$1.67B) and fruits ($0.62B, $0.23-$1.22B) (**Table 3**).

Among overall population subgroups, the total 5-year medical costs for diet-attributable cancers were significantly higher among whites compared to blacks and other racial groups, among men compared to women, and among individuals aged 65+) compared to those aged 20-44 years, 45-54 years and 55-64 years (**Table 4**). Adjusted for population size, the per person medical costs for diet-attributable cancers were higher among blacks and other racial/ethnic groups than whites, and among younger individuals (ages 20-64 years) than older individuals (ages 65+ years) but these differences were not statistically significant. Per-person medical costs among males ($14,575, $11,195-$18,302) were significantly higher than for females ($5868, $4664-$7212) (Table 4). eTable3 presents the 5-year direct medical costs of cancer care attributable to suboptimal diet for each cancer site, dietary factor and demographic strata.

Discussion

The estimated 5-year medical costs of new cancer cases in 2015 attributable to diet among US adults was $7.44 billion (2018$). Each of these costs represent only the 5-year direct medical expenditures for payers for new cancer cases diagnosed in that year. Thus, assuming similar incidence and costs of diet-attributable cancer cases in the years before and after each index year, the total 5-year cost for payers would be approximately 5-fold higher. Because out-of-pocket costs (including premium, deductibles and co-payments), and other indirect medical costs for individuals represent a substantial proportion of total medical expenditures in the US, total costs of diet-attributable cancer cases would be even higher.

The highest diet-attributable medical costs were estimated for cancers of the digestive system, including colorectal cancer, cancer of mouth and pharynx, and stomach. Low consumption of whole grains was the largest dietary contributor to these costs due to the very low consumption of whole grains among US adults (0.9 servings/d [6], compared with recommended 3-4 servings/d [21]), the strong association with colorectal cancer, and the high incidence of colorectal cancer which is the third most common cancer diagnosed in both men and women in the US. While whole grain intake has modestly increased in the US since 2000 [22], consumption levels remain far below recommendations. Low consumption of dairy and high consumption of processed meats were the next largest contributors to the direct medical costs of diet-attributable cancers. Based on the most recent WCRF/AICR review, the evidence-base for dairy consumption and lower colorectal cancer risk is strong, while evidence for harms for prostate cancer is now limited [9]. Since 1999 total consumption of dairy products (about 1.4 serving/d) [9, 23] among US adults has remained stable, lower than the recommended 3 servings/day [21]. For processed meat, the evidence is strong for increased risk of colorectal cancer and stomach cancer [9]. Interestingly, while intake of unprocessed red meat has modestly declined in the US since 1999, largely replaced by poultry, levels of processed meat intake have not declined [24]; and about 25% of the meat and poultry that American consume are processed meats [9, 23], The novel modeled estimates presented in this paper highlight the potential economic gains of new strategies to close these gaps and encourage healthier diets in the US. We estimated that nearly 10% of the medical costs for diet-attributable cancers was mediated through obesity.

Given the large economic burdens of cancer attributable to both direct dietary effects and diet-related weight gain, innovative and effective nutrition interventions at the population level may be needed for cancer prevention in the US [25]. A number of evidence-based and cost-effective interventions have been identified in previous literature to improve nutrition at the population level. These include media and education, nutrition labeling, subsidies for healthful foods and taxes for less healthful foods such as SSBs, incentives for healthy nutrition among Supplemental Nutrition Assistance Program recipients, healthy food prescriptions in Medicare/Medicaid, and comprehensive multicomponent interventions at the school and workplace level [26-29].

Disparities in the economic burden of diet-attributable cancer were observed in key population subgroups. Higher per-person costs among men are consistent with an overall worse diet, on average, among men than women [22]. The higher costs among younger adults likely relate to the higher cancer costs among patients diagnosed with cancer at a younger age [15], worse dietary intake patterns among young adults [30], and higher 5-year survival rates (and thus total costs) at younger ages for certain cancers [31-33]. Blacks and other races faced a disproportionate economic burden of cancers attributable to diet compared to whites, which may be due to an overall worse diet among minority racial groups [30]. Those living in socioeconomically disadvantaged communities could benefit from efforts to improve access to affordable healthy foods. It would be beneficial to evaluate the effectiveness of targeted nutrition programs and policies to improve diet and reduce diet-associated health disparities.

This investigation has several strengths. We used the most recent and nationally representative data on demographics and dietary habits among US adults, thereby increasing generalizability. We used a validated CRA model to generate population attributable fractions of diet-associated cancer burden [6, 34], a commonly used Markov Cohort model to estimate 5-year direct medical cost estimates of cancer care [2], and a validated method to project cancer incidence over time [35, 36]. Dietary intake data were based on 1 or 2-day diet recalls and corrected for within vs. between person variation and for total energy intake, reducing measurement error and improving estimation of habitual intake.

Our study has several limitations. There was insufficient evidence to quantify potential heterogeneous associations between diet and cancer by age, sex, or race groups, which may underestimate health and economic burdens if relative risk estimates derived from predominantly white study populations are smaller than seen in higher-risk groups. We did not consider the potential impact on cancer risk of poor diet during childhood and adolescence, which is an important area for future investigation. We did not account for potential interactions of dietary factors on cancer risk, which could cause higher or lower estimated risks and economic burdens. However, most diet-cancer RR estimates were derived from studies adjusting for multiple other dietary factors; and we used proportional multiplication and not summation to avoid overestimating joint PAFs [6]. Dietary intakes are invariably measured with error, which could increase uncertainty in the burden estimates. Net costs of cancer care represent averages, not matched for comorbidities; however, further matching on comorbidity does not change national cost estimates significantly [14]. The ratios we used to derive phase-specific direct medical costs of cancer among those age<65 years are based on a study conducted nearly twenty years ago [18]. However, the same methodology was used by Mariotto et al. (2011) [2] in their paper and we were unable to find any other validated ratios in the literature.

To our knowledge, this is the first study to estimate the economic burden of cancers attributable to suboptimal diet among adults in the US. The modeled estimates presented in this paper suggest substantial economic costs nationally, and relatively higher per person costs among young adults, men, and blacks; and that these burdens are projected to increase. These results may help to inform evidence-based priorities to improve diet and reduce cancer burden and costs in the US.

Declarations

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Conflicts of Interest: Dr. Mozaffarian reports honoraria or consulting from AstraZeneca, Acasti Pharma, GOED, Haas Avocado Board, Nutrition Impact, Pollock Communications, Boston Heart Diagnostics, and Bunge; scientific advisory board, Omada Health and Elysium Health; chapter royalties from UpToDate, and research funding from National Institutes for Health and Gates Foundation.

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Availability of data and material: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability: The codes used during the current study are available from the corresponding author on reasonable request.

Author Contributions: Jaya Shankar Khushalani (J.S.K), Fang Fang Zhang (F.Z), and Donatus Ekwueme (D.E) designed research; J.S.K and Frederick Cudhea (F.C.) conducted research; J.S.K, F.C, Zhilei Shan (Z.S), and Mengyuan Ruan (M.R) analyzed data. J.S.K wrote the first draft and all authors commented on previous versions of the manuscript. J.S.K had primary responsibility for final content. All authors read and approved the final manuscript.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention

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Tables

Table 1. Dietary Factors, Related Cancer Outcomes, Cancer Relative Risks, and Effect Estimates on Body Mass Index[a]

Dietary Factors	Cancers associated via direct risk	Unit of RR	Cancer RR (95% UI) Per Unit of RR[b]	Effect Estimates on BMI kg/m^2 (95% UI) (Per 1 serving/d)[c]
Fruits	Mouth and pharynx, and Larynx cancer	1 serving/day (100 g)	0.95 (0.91, 1.00)	For baseline BMI <25: -0.06 (-0.08, -0.04) For baseline BMI ≥25: -0.11 (-0.16, -0.06)
Vegetables	Mouth and pharynx, and Larynx cancer	1 serving/day (100 g)	0.91 (0.87, 0.96)	For baseline BMI <25: -0.03 (-0.04, -0.01) For baseline BMI ≥25: -0.06 (-0.09, -0.02)
Whole grains	Colorectal cancer	1 serving/day (90 g)	0.83 (0.78, 0.89)	For baseline BMI <25: -0.05 (-0.07, -0.03) For baseline BMI ≥25: -0.08 (-0.10, -0.06)
Processed meats	Colorectal and Stomach cancer	1 serving/day (50 g)	Colorectal: 1.16 (1.08, 1.26) Stomach: 1.18 (1.01, 1.38)	For baseline BMI <25: 0.13 (0.07, 0.19) For baseline BMI ≥25: 0.16 (0.11, 0.21)
Red meats	Colorectal cancer	1 serving/day (100 g)	1.12 (1.00, 1.25)	For baseline BMI <25: 0.13 (0.07, 0.20) For baseline BMI ≥25: 0.23 (0.14, 0.32)
Dairy	Colorectal cancer	1.6 servings/day (400 g)	0.87 (0.83, 0.90)	*No effect estimates of dairy products on BMI*
SSBs	No cancers associated with direct risk	*No direct RR of SSB on cancer*		For baseline BMI <25: 0.09 (0.05, 0.14) For baseline BMI ≥25: 0.23 (0.14, 0.32)

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RR=Relative Risk; BMI=Body Mass Index; UI=Uncertainty Interval

[a]This table is adapted from Zhang et al. (2019)[6]

[b]RR estimates were based on meta-analyses of prospective cohort studies with limited evidence of bias from confounding, where the associations were multivariable adjusted and independent of obesity.

[c]Obesity is associated with an increased risk of 13 cancers (colorectal, stomach, post-menopausal breast, ovary, corpus uteri, advanced prostate, liver, kidney, pancreas, gallbladder, thyroid, multiple myeloma, esophageal adenocarcinoma). Although there is no direct RR for SSB and cancer, SSB can increase the risk of cancer mediated through obesity. There are no effect estimates of dairy products on obesity.

Table 2. Estimated five-year medical costs (2018 billion $) of new cancer cases diagnosed in 2015, total and attributable to suboptimal diet, by cancer site

Cancer site	Number of new cancer cases (95% UI)[a]	5-year medical cost[b] of cancer care attributable to suboptimal diet (95% UI)[c]				5-year medical cost of cancer care (95% UI)[d]
		Direct[e]	Indirect[f]	Total	% of total 5-year medical cost of cancer care[g]	
Post-menopausal breast	1,900 (1,443-2,392)	0 (0-0)	0.09 (0.08-0.12)	0.09 (0.08-0.12)	0.86 (0.7-1.04)	10.45 (10.29-10.62)
Ovary	107 (64-157)	0 (0-0)	0.01 (0.01-0.02)	0.01 (0.01-0.02)	0.46 (0.31-0.64)	2.81 (2.74-2.88)
Corpus uteri	1,935 (1,561-2,313)	0 (0-0)	0.11 (0.09-0.13)	0.11 (0.09-0.13)	3.39 (2.88-3.92)	3.17 (3.08-3.27)
Advanced Prostate	327 (146-536)	0 (0-0)	0.03 (0.02-0.04)	0.03 (0.02-0.04)	0.7 (0.44-0.96)	3.51 (3.33-3.71)
Kidney	1,408 (1,191-1,632)	0 (0-0)	0.11 (0.09-0.13)	0.11 (0.09-0.13)	2.3 (1.96-2.66)	4.64 (4.47-4.82)
Liver	803 (630-997)	0 (0-0)	0.07 (0.05-0.09)	0.07 (0.05-0.09)	2.3 (1.83-2.82)	2.94 (2.8-3.08)
Pancreas	404 (314-501)	0 (0-0)	0.04 (0.03-0.05)	0.04 (0.03-0.05)	0.81 (0.65-0.99)	4.6 (4.46-4.74)
Multiple myeloma	205 (143-277)	0 (0-0)	0.03 (0.02-0.05)	0.03 (0.02-0.05)	0.74 (0.52-1)	4.41 (4.25-4.57)
Thyroid	264 (195-337)	0 (0-0)	0.01 (0.01-0.02)	0.01 (0.01-0.02)	0.51 (0.38-0.64)	2.06 (1.87-2.27)

Cancer site	**Number of new cancer cases (95% UI)**[a]	**5-year medical cost**[b] **of cancer care attributable to suboptimal diet (95% UI)**[c]				**5-year medical cost of cancer care (95% UI)**[d]
		Direct[e]	Indirect[f]	Total	% of total 5-year medical cost of cancer care[g]	
Gallbladder	74 (57-92)	0 (0-0)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	1.81 (1.49-2.11)	0.38 (0.35-0.42)
Esophageal adenocarcinoma	368 (276-469)	0 (0-0)	0.04 (0.03-0.05)	0.04 (0.03-0.05)	3.46 (2.93-4.04)	1.06 (1.02-1.11)
Larynx	3,034 (2,177-3,820)	0.26 (0.17-0.37)	0 (0-0)	0.26 (0.17-0.37)	25.57 (17.13-34.32)	0.98 (0.92-1.04)
Mouth and pharynx	12,730 (9,642-15,750)	1.09 (0.7-1.54)	0 (0-0)	1.09 (0.7-1.54)	25.55 (16.95-35)	4.06 (3.92-4.2)
Colorectal	60,748 (51,832-69,462)	5.28 (4.35-6.21)	0.07 (0.03-0.12)	5.32 (4.43-6.22)	36.88 (31.25-42.36)	13.8 (13.56-14.05)
Stomach	151 (98-213)	0.2 (0.06-0.41)	0.01 (0.01-0.02)	0.21 (0.07-0.43)	7.94 (2.62-15.52)	2.55 (2.46-2.65)
All cancer sites	84,459 (69,766-98,947)	6.83 (5.27-8.52)	0.64 (0.47-0.84)	7.44 (5.79-9.27)	11.58 (9.31-13.97)	61.44 (59.52-63.44)

This table is original to the manuscript

UI = Uncertainty Interval. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[a]For each cancer type, new cancer cases attributable to diet were estimated using the Comparative Risk Assessment model using cancer incidence and Joint Population Attributable fraction. For cancer with more than one associated dietary factor, joint PAFs were computed using the proportional multiplication

formula for cumulative effects, such that the joint PAF is less than the sum of the PAFs for the contributing dietary factors. The cancer incidence in 2015 was used to generate the estimates of new cancer cases attributable to diet. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[b] All costs are reported in 2018 billion $.

[c]The 5-year medical costs for cancers attributable to diet were computed using a Markov cohort model that incorporates cancer incidence, Population attributable fraction, monthly phase-specific costs of cancer care and monthly probability of death due to cancer and other causes. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[d]The total 5-year medical costs attributable to diet were computed using a Markov cohort model that incorporates cancer incidence, monthly phase-specific costs of cancer care and monthly probability of death due to cancer and other causes. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[e]These are the 5-year medical costs for cancers attributable to direct effect of dietary factors.

[f]These are the 5-year medical costs for cancers attributable to obesity-mediated effect of dietary factors. Total costs are a sum of medical costs for cancers attributable to both direct and obesity-mediated effects of dietary factors.

[g]Computed as (Total 5-year costs of cancer care attributable to diet/5-year medical cost of cancer care for cases diagnosed in the same year)*100.

Table 3. Estimated five-year medical costs (2018 billion $) of new cancers diagnosed in 2015 attributable to suboptimal diet, by dietary factors and type of association

Dietary factor[a]	5-year medical cost[b] of cancer care attributable to dietary factor (95% UI)		
	Direct association[c]	Obesity-mediated association[d]	Total
Low Consumption of whole grain	2.66 (1.88-3.55)	0.09 (0.05-1.4)	2.76 (1.89-4.96)
Low consumption of fruits	0.46 (0.15-0.94)	0.16 (0.09-0.27)	0.62 (0.23-1.22)
Low consumption of vegetables	0.99 (0.54-1.48)	0.1 (0.05-0.19)	1.09 (0.59-1.67)
Low consumption of dairy	1.83 (1.35-2.34)	0 (0-0)	1.82 (1.34-2.36)
High consumption of sugar-sweetened beverages	0 (0-0)	0.13 (0.05-0.25)	0.13 (0.05-0.25)
High consumption of red meat	0.47 (0.14-1.03)	0.06 (0.03-0.09)	0.54 (0.17-1.11)
High consumption of processed meat	1.4 (0.72-2.29)	0.11 (0.05-0.21)	1.5 (0.77-2.48)

This table is original to the manuscript

UI = Uncertainty Intervals. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[a]The 5-year medical costs for cancers attributable to each dietary factor were obtained by summing the costs for all cancer sites attributable to the particular dietary factor. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[b]All costs are reported in 2018 billion $

[c]These are the 5-year medical costs for cancers attributable to direct effect of each dietary factor.

[d]These are the 5-year medical costs for cancers attributable to obesity-mediated effect of dietary factors. Total costs are a sum of medical costs for cancers attributable to both direct and obesity-mediated effects of each dietary factor.

Table 4. Estimated total and per-patient five-year medical costs of new cancer cases diagnosed in 2015 attributable to suboptimal diet, by demographic factors

Demographic group[a]		5-year medical cost[b] of cancer care attributable to suboptimal diet	
		Total cost in 2018 billion $ (95% UI)	Cost per cancer patient in 2018 $ (95% UI)[c]
Race	White	5.96 (4.64-7.43)	8,963 (6,968-11,172)
	Black	1.08 (0.85-1.34)	11,068 (8,699-13,670)
	Other	0.38 (0.29-0.48)	9,469 (7,338-11,895)
Sex	Males	4.53 (3.48-5.69)	14,575 (11,195-18,302)
	Females	2.9 (2.3-3.56)	5,868 (4,664-7,212)
Age	20-44 years	0.52 (0.41-0.64)	11,858 (9,384-14,550)
	45-54 years	1.27 (0.99-1.57)	11,786 (9,235-14,620)
	55-64 years	2.16 (1.67-2.7)	9,754 (7,535-12,193)
	65+	3.48 (2.71-4.34)	8,063 (6,278-10,054)

This table is original to the manuscript

UI = Uncertainty Intervals. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[a]The 5-year medical costs for cancers attributable to suboptimal diet for each demographic group were obtained by summing the costs across all cancer sites for each demographic group. 95% UIs were obtained through Monte Carlo simulation using 1000 iterations.

[b]The cost per cancer patient is obtained by dividing the cost for each demographic group by the cancer incidence for each demographic group.

Supplementary Files

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- SupplementaryDataCCC.docx