Published in final edited form as:

Cancer Causes Control. 2015 February ; 26(2): 277–286. doi:10.1007/s10552-014-0509-9.

Concordance with World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) guidelines for cancer prevention and obesity-related cancer risk in the Framingham Offspring cohort (1991–2008)

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Abstract

Purpose—This prospective cohort study evaluates associations between healthful behaviors consistent with WCRF/AICR cancer prevention guidelines and obesity-related cancer risk, as a third of cancers are estimated to be preventable.

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Conflict of interest The American Cancer Society did not have a role in study design, collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication. The authors have no conflicts of interest to report.

Methods—The study sample consisted of adults from the Framingham Offspring cohort ($n = 2,983$). From 1991 to 2008, 480 incident doctor-diagnosed obesity-related cancers were identified. Data on diet, measured by a food frequency questionnaire, anthropometric measures, and self-reported physical activity, collected in 1991 was used to construct a 7-component score based on recommendations for body fatness, physical activity, foods that promote weight gain, plant foods, animal foods, alcohol, and food preservation, processing, and preparation. Multivariable Cox regression models were used to estimate associations between the computed score, its components, and subcomponents in relation to obesity-related cancer risk.

Results—The overall score was not associated with obesity-related cancer risk after adjusting for age, sex, smoking, energy, and preexisting conditions (HR 0.94, 95 % CI 0.86–1.02). When score components were evaluated separately, for every unit increment in the alcohol score, there was 29 % lower risk of obesity-related cancers (HR 0.71, 95 % CI 0.51–0.99) and 49–71 % reduced risk of breast, prostate, and colorectal cancers. Every unit increment in the subcomponent score for non-starchy plant foods (fruits, vegetables, and legumes) among participants who consume starchy vegetables was associated with 66 % reduced risk of colorectal cancer (HR 0.44, 95 % CI 0.22–0.88).

Conclusions—Lower alcohol consumption and a plant-based diet consistent with the cancer prevention guidelines were associated with reduced risk of obesity-related cancers in this population.

Keywords

Healthful behaviors; American Institute for Cancer Research; Cancer prevention guidelines; Cancer; Framingham Heart Study

Introduction

In the USA, cancer incidence has risen over the past two decades [1, 2] with over 1.6 million incident cancer cases anticipated in 2014 [2]. It is estimated that one-third of incident cancers are related to adiposity, poor diet, and physical inactivity and are therefore preventable [3]. In 1997, the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR) released cancer prevention guidelines advising on weight management, diet, and physical activity [4], which were updated in 2007 [3]. These guidelines provide an integrated approach for establishing healthy eating and physical activity habits and serve as a basis for policies, programs, and personal choices that reduce cancer incidence.

While research has focused on the role of specific nutrients in cancer risk, it is important to evaluate whether lifestyle choices, collectively and individually, that are consistent with current cancer prevention guidelines are effective in reducing the cancer burden due to the multifactorial and cumulative nature of cancer risk [3]. Since the release of the 1997 WCRF/AICR guidelines [4], several studies have operationalized them to elucidate how they are associated with cardiovascular disease, cancer and mortality [5–8]. Overall concordance to these guidelines has been studied in relation to cancer risk in postmenopausal females [5, 6] and Europeans [7]. These results need to be confirmed in an aging sample of American men

and women, where social and environmental factors that influence diet, physical activity patterns, and cancer risk may be different from Europe. It is also informative to assess the concordance to the individual guidelines in relation to cancer risk, as certain recommendations may have a stronger impact on cancer risk. The objective of the present study was to investigate whether healthful behaviors in concordance with the WCRF/AICR cancer prevention guidelines are associated with risk of obesity-related cancers and three of the most common site-specific cancers (breast, prostate, and colon) in the Framingham Offspring (FOS) cohort. The analysis was limited to obesity-related cancers due to their hypothesized association with lifestyle factors.

Materials and methods

Study population

The analytic sample consists of 2,983 men and women from the Offspring generation of the Framingham Heart Study (FHS), an ongoing study in Framingham, Massachusetts [9, 10]. Clinical and medical exams were conducted, on average, every 4 years since 1971–1975 [10, 11]. Dietary data collection for the FOS cohort began at exam 5 in 1991. The FOS cohort consists of 3,799 men and women at exam 5, but only 3,418 participants have collected dietary data. The analytical dataset was restricted to participants with caloric intake within the ranges of 600–4,199 and 600–3,999 kcal/day for men and women, respectively, in consistency with the criteria for “plausible intakes” established by the FHS. Participants who left 13 blanks on the food frequency questionnaire (FFQ) were excluded by the FHS investigators. Based on the calorie cutoffs and the number of acceptable blanks, there were 3,351 participants with valid dietary data. Participants with a history of cancer at or prior to exam 5 ($n = 366$) and pregnant women at exam 5 ($n = 2$) were also excluded. All research activities were consistent with the ethical standards of New York University’s Institutional Review Board.

Data collection

Diet—Diet was assessed using the validated 126-item Harvard semi-quantitative FFQ that queried the frequency of food intake with standard serving sizes [12]. FFQs were mailed to participants and reviewed by trained personnel at each study visit for accuracy. Participants reported the frequency of food consumption over the past year. The US Department of Agriculture nutrient database was used to analyze the FFQ data [12].

Physical activity—Participants reported the time they spent resting or engaging in light, moderate, or heavy physical activity on an average day [13]. A physical activity index (PAI) was computed by multiplying the time spent at each activity (hours/week) by its metabolic cost [13, 14] and then summing the weighted hours, as previously published in FHS.

Outcome—The primary outcome of interest was obesity-related cancers, which include gastrointestinal tract, reticuloendothelial system (blood, bone, and spleen), female reproductive tracts, genitourinary organs, and the thyroid gland cancers [15, 16]. Cancers were considered obesity-related, if identified by the American Cancer Society as clearly or possibly linked to excess adiposity [15]. Cancer cases were ascertained using pathology

reports with some diagnoses based solely on death certificates or clinical diagnoses. Self-reported or suspected diagnoses not confirmed by pathologic reports were excluded. Cancer type and date of diagnosis were obtained from the patient's medical records. In these analyses, 480 primary cases of obesity-related cancers including 124 breast, 153 prostate, and 63 colorectal cancers were identified.

Other variables—Anthropometric measures including height and weight were measured by trained personnel at exam 5 and were used to calculate body mass index (BMI). Age and smoking status were self-reported during in-person interviewing. Menopausal status was determined using a standardized medical history questionnaire, and use of hormone replacement therapy was ascertained by the examining physician.

Operationalization of WCRF/AICR guidelines

A 7-point score was created based on concordance with WCRF/AICR recommendations including (1) body fatness, (2) physical activity, (3) foods and drinks that promote weight gain, (4) plant foods, (5) animal foods, (6) alcohol consumption, and (7) food preservation, processing, and preparation. All recommendations contributed 1 point to the total score resulting in a score range from 0 to 7 such that higher scores reflect greater concordance with the guidelines. The details of score operationalization are described in Table 1. Briefly, the score components including body fatness (no operationalized subcomponents), physical activity, animal foods, and alcohol (no existing subcomponents) provided quantitative recommendations. These criteria were used as cutoffs for assigning component scores such that participants received 1, 0.5, or 0 points when the recommendation was met, partially met, or not met, respectively.

For components with operationalized subcomponents including plant foods, foods and drinks that promote weight gain and preservation, processing, and preparation, the subcomponents were scored first. Subcomponents with quantitative recommendations including fruits and vegetables and sodium were assigned a score using these criteria as cutoffs. Participants received 1, 0.5, or 0 points when the recommendation was met, partially met, and not met, respectively. For subcomponents with no quantitative recommendations including energy-dense foods, sugary drinks, refined grains and salty foods, data-driven tertiles were used to assign the subcomponent scores. Participants received 1, 0.5, or 0 points if they were in the lowest, middle, highest tertile of consumption, respectively. To score the subcomponent representing non-starchy plant foods when consuming starchy vegetables (recommendation 4d), a median cutoff was used. Participants who had low starchy and high non-starchy plant food consumption received 1 point. Participants who had high starchy and non-starchy plant food consumption received 0.5 points. Participants with low non-starchy plant food consumption received 0 points, regardless of the level of starchy vegetable consumption. The component score was the sum of the individual subcomponent scores. The overall score was computed by obtaining the weighted average such that each component contributed a maximum score of one.

Statistical analyses

Descriptive statistics were generated to examine clinical, dietary and demographic characteristics at exam 5, the first exam at which dietary data were collected (Table 2). Cox proportional hazard models were used to evaluate the impact of the overall score, its components, and subcomponents on obesity-related cancer risk. Participants who were lost to follow-up or died from other causes were censored. Hazard ratios (HR) and 95 % confidence intervals (CI) for every 1-unit increment of the overall score, its components, and subcomponents were computed for obesity-related cancers combined and then in exploratory analyses for site-specific cancers. These HRs were adjusted for age and then for other covariates including sex, smoking, preexisting conditions (cardiovascular disease and diabetes), menopausal status and hormone use where applicable. Covariates with an impact of >10 % on HRs were retained in the final models. A 1-unit increment represents a 1-point increase in total score, a 0.5-point increase in component (without subcomponents) or subcomponent scores, and a 0.25 and 0.167 increase in component scores with 2 and 3 subcomponents, respectively. These increments represent an improvement from one category of a component and/or subcomponent score to the other (not meeting, half meeting, or fully meeting a recommendation). All analyses were conducted in 2013–2014 using SAS v 9.3 (Cary NC).

Results

Characteristics of study population

Table 2 presents the population characteristics evaluated at exam 5. The mean age was 66 years, and the mean BMI was 28.3 kg/m² indicating that the study sample, on average, was middle-aged to older and overweight. The average PAI was 35.7, which represents a relatively high level of physical activity [13]. Furthermore, almost half of the population identified as a former smoker (51.1 %). The mean energy intake was 1,858 kcal/day with approximately half of energy being derived from carbohydrates and a third from fats. In FOS, total score values ranged from 0 to 6.75, while the component and subcomponent score values all ranged from 0 to 1. The mean duration of follow-up was 11.5 years.

Obesity-related cancers

The overall score was not associated with obesity-related cancer risk, after adjusting for age only and then for age, sex and smoking (HR 0.94, 95 % CI 0.86–1.02) (Table 3). Further adjustment for energy, BMI and the presence of chronic diseases did not change these results. None of the score components were significantly associated with obesity-related cancer risk in both age-adjusted and multivariable-adjusted models. However, for every unit increment in the alcohol score, a 29 % lower risk of obesity-related cancers was observed after adjusting for age and other covariates (HR 0.71, 95 % CI 0.51–0.99).

Exploratory Analyses: site-specific cancers

Breast cancer—In analyses evaluating the overall score, its components, and subcomponents in relation to breast cancer risk (Table 4), for every unit increment in the overall score, there was a marginally significant 13 % lower risk of breast cancer (HR 0.87,

95 % CI 0.74–1.03) after adjustment for age and smoking. Additional adjustment for energy, menopausal status, hormone use and preexisting conditions did not alter these results. None of the score components, with the exception of alcohol, were significantly associated with breast cancer risk in age-adjusted or multivariable-adjusted models. For every unit increase in the score for the alcohol component, there was 49 % lower risk of breast cancer in multivariable-adjusted models (HR 0.51, 95 % CI 0.29–0.89).

Prostate cancer—The overall score was not associated with prostate cancer risk after adjusting for age and smoking (HR 1.08, 95 % CI 0.92–1.27) (Table 4). Additional adjustment for energy and preexisting conditions at baseline did not change these results. The physical activity, plant foods, and fruit and vegetable scores were associated with approximately a two-fold increase in prostate cancer risk for every 1-unit increment in multivariable-adjusted models (HR ranging from 1.83 to 2.29). However, for every unit increase in the score for the alcohol component, there was a 52 and 55 % decrease in prostate cancer risk in both age-adjusted and multivariable-adjusted (HR 0.45, 95 % CI 0.26–0.77) models, respectively. None of the remaining components and subcomponents were associated with prostate cancer risk.

Colorectal cancer—As observed for prostate cancer, no significant associations were detected between the overall score and colorectal cancer in age (HR 0.80, 95 % CI 0.64–1.01) and multivariable-adjusted (HR 0.87, 95 % CI 0.68–1.12) models. In age-adjusted models only, for every unit increment in the component score for animal foods, there was a 58 % reduction in colorectal cancer risk.

No significant associations were observed between the other score components and colorectal cancer risk except for alcohol, preservation, processing, and preparation, and intake of non-starchy and starchy plant foods. Sufficient intakes of non-starchy plant foods among starchy vegetable consumers were associated with 66 % lower colorectal cancer risk for every unit increment in this subcomponent score (HR 0.44, 95 % CI 0.22–0.88). Alcohol intake in concordance with WCRF/AICR guidelines had a protective impact. For every unit increment in the score for alcohol, 76 and 71 % lower colorectal cancer risk was observed in age-adjusted (HR 0.24, 95 % CI 0.12–0.45) and multivariable-adjusted (HR 0.29, 95 % CI 0.15–0.56) models, respectively. However, for every increment in the preservation, processing, and preparation score, there was more than a two-fold increase in colorectal cancer risk in multivariable-adjusted models (HR 2.56, 95 % CI 1.02–6.40). In particular, the sodium subcomponent score was associated with more than a three-fold increase in colorectal cancer risk after adjustment for age and other confounders (HR 3.50, 95 % CI 1.20–10.06).

Discussion

This study evaluated healthful behaviors congruent with the 2007 cancer prevention guidelines in relation to obesity-related cancers and the most common site-specific cancers. In this cohort of middle-aged Caucasian adults, the overall score, as a proxy for overall concordance to seven operationalized WCRF/AICR guidelines (out of nine applicable guidelines), was not associated with obesity-related cancer and site-specific cancer risk.

Among score components, adherence to the alcohol recommendation emerged as protective against obesity-related cancer risk and all site-specific cancers. Among score subcomponents, sufficient consumption of non-starchy plant foods was associated with decreased colorectal cancer risk. However, our finding that physical activity, plant foods and fruits and vegetables increase prostate cancer risk and that sodium increases colorectal cancer risk is not consistent with any previous literature and has no plausible biological mechanism. These findings could be attributed to chance due the limited number site-specific cancers in this cohort. The results observed for prostate cancer may potentially be due to increased prostate cancer screening and diagnosis among men with healthier behaviors (higher intake of plant foods, fruit and vegetables, and physical activity).

Four studies evaluated adherence to cancer prevention guidelines in relation to cancer risk [5–7, 17]. One study conducted in a European cohort [7] indicated that higher adherence to WCRF/AICR guidelines was associated with reduced risk of overall cancer, breast, and colorectal, but not prostate cancer. These results are inconsistent with findings of the present study, where the overall score was not related to risk of obesity-related, prostate, and colorectal cancers and only a modest borderline significant association was observed for breast cancer.

The remaining three studies were conducted in American female cohorts [5, 6, 17]. One study in the Iowa Women's Health Study cohort [5] showed that higher adherence to the 1997 WCRF/AICR guidelines was associated with a significant reduction in overall cancer risk. This result is inconsistent with our null finding for overall score in relation to obesity-related cancer risk. The ViTamins and Lifestyle Study (VITAL) cohort [6] showed that overall adherence to 2007 guidelines was associated with reduced postmenopausal breast cancer risk, which is consistent with the present study's finding of a borderline significant modest reduction in breast cancer risk. The study also found that meeting the recommendations for alcohol was associated with reduced breast cancer risk, which is also consistent with the present study's findings. A recent analysis in the Women's Health Initiative cohort [17] indicated that overall adherence to the ACS guidelines for cancer prevention was associated with lower risk of any cancer, breast cancer, and colon cancer. Associations were strongest among Asian, black, and Hispanic women and weakest among non-Hispanic Whites. This is inconsistent with our finding of null association for the overall score in relation to cancer risk, but suggestive that the lack of an association may be due to weaker associations among Whites.

The discrepancy between our study findings and those of the four previous studies may be ascribed to differences in study population characteristics and endpoints. The European study [7] was conducted in a population characterized by different social and environmental factors that affect dietary and physical activity patterns in addition to cancer risk. All American studies [5, 6, 17] were conducted in postmenopausal female cohorts, for which risk profile and associations may vary from a cohort of aging men and women (pre- and postmenopausal). Additionally, the endpoints of previous studies were different from our primary endpoint, which was obesity-related cancers. Moreover, the operationalization of the WCRF/AICR recommendations varied across the studies. Previous studies used definitions and quantitative cutoffs for body fatness, fruit and vegetable, and alcohol intake

that were consistent with the present study. However, definitions varied for the physical activity score (indices vs. MET values), energy-dense foods [6], and red meat intake [5]; processed meat intake was only considered in the EPIC cohort [7]. Studies also differed in scoring, as the VITAL and Iowa Women's Health Study [5, 6] did not provide a score for participants who partially met a recommendation in contrary to the EPIC study [7]. In contrast to previous studies, the present study used data-driven approaches (tertile and median cutoffs) to operationalize recommendations that did not provide quantitative cutoffs.

Although the present study evaluated cancer prevention guidelines, individually and cumulatively, in relation to lifestyle-related cancers, the results of this study should be interpreted in light of some limitations. Firstly, our overall score reflects seven out of nine applicable cancer prevention guidelines and eleven out of twenty subrecommendations. The score was constructed by assigning the WCRF/AICR recommendations for cancer prevention with equal weights. Therefore, the lack of an association between the overall score and cancer risk may have been, at least in part, due to the constructed score underestimating the potential impact of adhering to certain recommendations. Additionally, the use of categorical versus continuous variables for certain recommendations (BMI, PAI, fruits and vegetables, animal foods, and alcohol) may have underestimated their impact on cancer risk. Moreover, some WCRF/AICR guidelines [3] do not provide quantitative recommendations; therefore, data-driven approaches were used for scoring certain guidelines resulting in increased potential for misclassification.

Diet, physical activity, and BMI assessed at baseline were considered for this analysis. This may not be reflective of the participants' lifetime intake, activity level and body fatness, or during the critical exposure window that affects cancer risk and does not capture changes over time. As inherent to observational studies that use FFQs, self-reported intakes are prone to recall bias [18] and to underreporting [19], which may have biased associations toward the null. Participants were primarily Caucasian, so results may not be generalizable to other ethnic groups for which associations between adherence to guidelines and cancer risk may be stronger [17].

The study has notable strengths including its prospective design, long duration of follow-up of approximately two decades, use of a validated FFQ, assessment of anthropometric measures by trained personnel, and the use of medical records to ascertain cancer incidence.

In conclusion, certain healthful behaviors, namely adherence to alcohol recommendations and sufficient non-starchy plant food consumption, were the strongest predictors of cancer risk in this study. Studies that evaluate lifestyle and healthful behaviors in relation to cancer have important clinical and public health implications. They guide clinicians and policy makers in providing preventative care to patients by helping them navigate their food environment. Based on this study's results, dietary advice on cancer should emphasize the importance of adequate consumption of non-starchy plant foods especially among patients who consume starchy vegetables and of restricting alcohol consumption. Public health and policy initiatives to reduce alcohol and promote a plant-based diet may also help reduce the cancer burden. Future research should focus on evaluating associations between healthful

behaviors and cancer among different racial groups, particularly to tailor public health recommendations and policy initiatives to these groups.

Acknowledgments

This research was supported by the American Cancer Society Research Scholar Grant (#RSG-12-005-01-CNE) awarded to Niyati Parekh, PhD RD. The Framingham Heart Study is conducted and supported by the National Heart, Lung, and Blood Institute (NHLBI) in collaboration with Boston University (Contract No. N01-HC-25195). Funding support for the Framingham Food Frequency Questionnaire datasets was provided by ARS Contract #53-3k06-5-10, ARS Agreement #'s 58-1950-9-001, 58-1950-4-401, and 58-1950-7-707. This manuscript was not prepared in collaboration with investigators of the Framingham Heart Study and does not necessarily reflect the opinions or views of the Framingham Heart Study, Boston University, or NHLBI.

References

1. Silverberg E, Boring C, Squires T. Cancer statistics 1990. *CA Cancer J Clin.* 2008; 40(1):9–26.
2. Siegel R, Ma J, Zou Z, Jemal A. Cancer statistics, 2014. *CA Cancer J Clin.* 2014; 64(1):9–29. [PubMed: 24399786]
3. World Cancer Research Fund and American Institute for Cancer Research. Food, nutrition and the prevention of cancer: a global perspective. American Institute of Cancer Research; Washington: 2007.
4. World Cancer Research Fund and American Institute for Cancer Research. Food, nutrition and the prevention of cancer: a global perspective. American Institute of Cancer Research; Washington: 1997.
5. Cerhan JR, Potter JD, Gilmore JM, Janney CA, Kushi LH, Lazovich D, et al. Adherence to the AICR cancer prevention recommendations and subsequent morbidity and mortality in the Iowa women's health study cohort. *Cancer Epidemiol Biomark Prev.* 2004; 13(7):1114–1120.
6. Hastert TA, Beresford SA, Patterson RE, Kristal AR, White E. Adherence to WCRF/AICR cancer prevention recommendations and risk of post-menopausal breast cancer. *Cancer Epidemiol Biomark Prev.* 2013; 22:1498–1508.
7. Romaguera D, Vergnaud A, Peeters PH, van Gils CH, Chan DS, Ferrari P, et al. Is concordance with World Cancer Research Fund/American Institute for Cancer Research guidelines for cancer prevention related to subsequent risk of cancer? Results from the EPIC study. *Am J Clin Nutr.* 2012; 96(1):150–163. [PubMed: 22592101]
8. Vergnaud A, Romaguera D, Peeters PH, van Gils CH, Chan DS, Romieu I, et al. Adherence to the World Cancer Research Fund/American Institute for Cancer Research guidelines and risk of death in Europe: results from the European prospective investigation into nutrition and cancer cohort study. *Am J Clin Nutr.* 2013; 97(5):1107–1120. [PubMed: 23553166]
9. Dawber TR, Meadors GF, Moore FE Jr. Epidemiological approaches to heart disease: the Framingham study. *Am J Public Health Nations Health.* 1951; 41(3):279–281. [PubMed: 14819398]
10. Feinleib M, Kannel WB, Garrison RJ, McNamara PM, Castelli WP. The Framingham offspring study. Design and preliminary data. *Prev Med.* 1975; 4(4):518–525. [PubMed: 1208363]
11. Larson M, Atwood L, Benjamin E, Cupples LA, D'Agostino R, Fox C, et al. Framingham heart study 100 K project: genome-wide associations for cardiovascular disease outcomes. *BMC Med Genet.* 2007; 8(Suppl 1):S5. [PubMed: 17903304]
12. Rimm EB, Giovannucci EL, Stampfer MJ, Colditz GA, Litin LB, Willett WC. Reproducibility and validity of an expanded self-administered semiquantitative food frequency questionnaire among male health professionals. *Am J Epidemiol.* 1992; 135(10):1114–1126. [PubMed: 1632423]
13. Jonker JT, De Laet C, Franco OH, Peeters A, Mackenbach J, Nusselder WJ. Physical activity and life expectancy with and without diabetes life table analysis of the Framingham heart study. *Diabetes Care.* 2006; 29(1):38–43. [PubMed: 16373893]
14. Kannel WB, Sorlie P. Some health benefits of physical activity: the Framingham study. *Arch Intern Med.* 1979; 139(8):857. [PubMed: 464698]

15. American Cancer Society. Does body weight affect cancer?. 2014. <http://www.cancer.org/cancer/cancercauses/dietandphysicalactivity/bodyweightandcancerrisk/body-weight-and-cancer-risk-effects>. Accessed 10 Nov 2014
16. National Cancer Institute. Obesity and cancer risk. 2014. <http://www.cancer.gov/cancertopics/factsheet/Risk/obesity>. Accessed 10 Nov 2014
17. Thomson CA, McCullough ML, Wertheim BC, Chlebowski RT, Martinez ME, Stefanick ML, et al. Nutrition and physical activity cancer prevention guidelines, cancer risk, and mortality in the women's health initiative. *Cancer Prev Res*. 2014; 7(1):42–53.
18. Pope S, Kritchevsky S, Morris M, Block G, Tyllavsky F, Lee J, et al. Cognitive ability is associated with suspected reporting errors on food frequency questionnaires. *J Nutr Health Aging*. 2007; 11(1):55–58. [PubMed: 17315081]
19. Schatzkin A, Kipnis V, Carroll RJ, Midthune D, Subar AF, Bingham S, et al. A comparison of a food frequency questionnaire with a 24-hour recall for use in an epidemiological cohort study: results from the biomarker-based observing protein and energy nutrition (OPEN) study. *Int J Epidemiol*. 2003; 32(6):1054–1062. [PubMed: 14681273]

Table 1

Operationalization of WCRF/AICR recommendations for cancer prevention in the Framingham Offspring cohort

WCRF/AICR recommendations	Personal recommendations (subrecommendations)	Operationalization	Scoring
1. Body fatness: Be as lean as possible without becoming underweight	(1a) Ensure that body weight throughout childhood and adolescent growth projects toward the lower end of the normal BMI range at age 21 years	Insufficient data	N/A
	(1b) Maintain body weight within the normal range from age 21 years	BMI (kg/m ²)	
		18.5–24.9	1
		25–29.9	0.5
		<18.5 or >30	0
2. Physical activity: Be physically active as part of your everyday life	(1c) Avoid weight gain and increases in waist circumference throughout adulthood	Insufficient data	N/A
	(2a) Be moderately physically active, equivalent to brisk walking, for 30 min every day	PAI	
		>33 (high level)	1
		30–33 (moderate level)	0.5
		<30 (low level)	0
3. Foods and drinks that promote weight gain: Limit consumption of energy-dense foods; avoid sugary drinks	(2b) As fitness improves, aim for 60 min of moderate or for 30 min of vigorous physical activity every day	Insufficient data	N/A
	(2c) Limit sedentary habits such as watching television	Insufficient data	N/A
	(3a) Consume energy-dense foods (225–275 kcal/100 g) sparingly	ED foods (servings/week)	
		Tertile 1 (<29.8)	1
		Tertile 2 (29.8–48.8)	0.5
		Tertile 3 (48.9)	0
	(3b) Avoid sugary drinks	Sugary drinks (servings/week)	
		Tertile 1 (<4)	1
		Tertile 2 (4–9.40)	0.5
		Tertile 3 (9.41)	0
4. Plant foods: Eat mostly foods of plant origin	(3c) Consume fast foods sparingly, if at all	Overlapping category with ED foods	N/A
		F and V intake	
		5 servings/day	1
	(4a) Eat 5 portions/servings (>400 g) of a variety of non-starchy vegetables and of fruit every day	2.5 to <5 servings/day	0.5
		<2.5 servings/day	0
		Overlapping category with refined grains and consumption of non-starchy fruits, vegetables and pulses	N/A
	(4b) Eat relatively unprocessed cereals (grains) and/or pulses (legumes) with every meal	Refined grains (g/day)	
		Tertile 1 (<2.8)	1
		Tertile 2 (2.8–4.4)	0.5
		Tertile 3 (4.5)	0
	(4c) Limit refined starchy foods	Consumption of starchy vegetables (Median = 503 g/week) and non-starchy vegetables, fruits, and legumes (Median = 2,471.4 g/week)	
	(4d) People who consume starchy roots or tubers as staples should also ensure sufficient intake of non-starchy vegetables, fruit, and pulses (legumes) ^a		

WCRF/AICR recommendations	Personal recommendations (subrecommendations)	Operationalization	Scoring
		Starchy <503 g/week; Non-starchy >2,471.4 g/week	1
		Starchy >503 g/week; Non-starchy >2,471.4 g/week	0.5
		Starchy >503 g/week; Non-starchy <2,471.4 g/week	0
		Starchy <503 g/week; Non-starchy <2,471.4 g/week	0
5. Animal foods: Limit intake of red meat (beef, pork, lamb, and goat) and avoid processed meat	(5a) People who eat red meat should consume <500 g/week and very few, if any, processed meats	Red and processed meat intake	
		<500 g/week and <3 g/day	1
		<500 g/week and 3 to <50 g/day	0.5
		500 g/week or 50 g/day	0
6. Alcoholic drinks: Limit alcoholic drinks	(6a) If alcoholic drinks are consumed, limit consumption to 2 drinks/day for men and 1 drink/day for women	Ethanol intake (g/day)	
		28 (men)	1
		14 (women)	1
		28–42 (men)	0.5
		14–21 (women)	0.5
		>42 (men)	0
7. Preservation, processing, preparation: Limit consumption of salt. Avoid moldy cereals (grains) or pulses (legumes)	(7a) Avoid salt-preserved, salted, or salty foods; preserve foods without using salt ^b	Salty foods (servings/week)	
		Tertile 1 (<41.1)	1
		Tertile 2 (41.1–62.7)	0.5
		Tertile 3 (>62.7)	0
	(7b) Limit consumption of processed foods with added salt to ensure an intake of <6 g (2.4 g sodium)/day	Sodium intake (g/day)	
		<2.4	1
		2.4–3.6	0.5
		>3.6	0
	(7c) Do not eat moldy cereals (grains) or pulses (legumes)	Insufficient data	N/A
	(8a) Dietary supplements are not recommended for cancer prevention	Insufficient data	N/A
8. Dietary supplements: Aim to meet nutritional needs through diet alone	(8a) Dietary supplements are not recommended for cancer prevention	Insufficient data	N/A
S1. Breastfeeding: Mothers to breastfeed; children need to be breastfed	(S1a) Aim to breastfeed infants exclusively up to 6 months and continue with complementary feeding thereafter	Insufficient data	N/A
S2. Cancer survivors: Follow the recommendations for cancer prevention	(S2a) All cancer survivors should receive nutritional care from an appropriately trained professional	Not applicable to this population	N/A
	(S2b) If able to do so, and unless otherwise advised, aim to follow the recommendations for diet, healthy weight, and physical activity	Not applicable to this population	N/A

^aInclude yams/sweet potatoes, beets, potatoes, french fries, corn. All other fruits, vegetables, and pulses are considered non-starchy

^bInclude cottage/ricotta cheese, cream cheese, other cheese, butter, margarine, tomato sauce, red chili sauce, chicken, bacon, hotdogs, processed meats, hamburger, meat sandwich or casserole; canned tuna; cold cereal; white bread; dark bread; English muffin, muffins/biscuits; pancakes/waffles, French fries, chips, crackers; pizza, cookies, brownies, doughnuts, cakes, sweet rolls, pies, peanut butter, popcorn, nuts, chowder/cream soup, mayonnaise, mustard, and fried foods

PAI/Physical Activity Index, BMI/Body Mass Index, N/A Not Applicable

Table 2

Characteristics of participants in the Framingham Heart Study offspring cohort at exam 5 (baseline)^{a,b} (*n* = 2,983)

	Percentage/mean (SD)
<i>Clinical characteristics</i>	
Age (year)	66.0 (9.2)
Physical activity index	35.7 (5.6)
Smoking status (%)	
Never smoker	38.2 %
Former smoker	51.1 %
Current smoker	10.7 %
BMI (kg/m ²)	28.3 (5.4)
Sex (%)	
Female	53.7 %
Menopausal status (%)	
Postmenopausal	63.9 %
<i>Diet</i>	
Total calories (kcal)	1,858.1 (630.1)
Total carbohydrates (% kcal)	47.7 (8.9)
Total protein (% kcal)	17.7 (3.6)
Total fat (% kcal)	31.6 (6.8)
Energy-dense foods (servings/week)	43.4 (24.9)
Sugary drinks (servings/week)	8.7 (8.76)
Fruits and vegetables (servings/day)	3.7 (2.33)
Whole grains (oz equivalents/day)	1.2 (1.24)
Refined grains (oz equivalents/day)	4.0 (2.13)
Red Meat (g/week)	328.3 (247.9)
Processed meat (g/week)	78.5 (99.3)
Alcohol (g/day)	7.5 (13.1)

FHS Framingham Heart Study, *BMI* body mass index

^a Continuous variables presented as Mean ± SD

^b Categorical variables presented as percentage of study population

Table 3

Age and multivariable-adjusted^a Hazard Ratios (95 % CI) for obesity-related cancers per unit of the total score and its components from exam 5 in 1991^b

	No. of participants	Age-adjusted HR (95 % CI)	Multivariable-adjusted HR (95 % CI)
Total score	2,971	0.92 (0.85–1.00)	0.94 (0.86–1.02)
1. Body mass index (body fatness)	2,929	0.95 (0.75–1.20)	1.00 (0.79–1.28)
2. Physical activity	2,914	0.86 (0.67–1.12)	0.87 (0.67–1.12)
3. Foods and beverages that promote weight gain	2,971	0.95 (0.72–1.27)	1.00 (0.75–1.34)
3a. Energy-dense foods	2,971	1.05 (0.84–1.31)	1.08 (0.87–1.35)
3b. Sugary drinks	2,971	0.90 (0.72–1.12)	0.93 (0.74–1.16)
4. Plant foods	2,971	1.09 (0.76–1.55)	1.18 (0.82–1.70)
4a. Fruits and vegetables	2,971	1.00 (0.78–1.28)	1.05 (0.82–1.35)
4b. Refined grains	2,971	1.11 (0.89–1.39)	1.13 (0.91–1.41)
4c. Non-starchy and starchy plant foods	2,971	1.00 (0.81–1.24)	1.04 (0.84–1.29)
5. Animal foods	2,970	0.95 (0.74–1.23)	1.02 (0.78–1.33)
6. Alcohol	2,965	<i>0.72 (0.52–1.00)</i>	<i>0.71 (0.51–0.99)</i>
7. Preservation, processing and preparation	2,971	1.21 (0.90–1.64)	1.26 (0.94–1.71)
7a. Salty foods	2,971	1.05 (0.84–1.31)	1.07 (0.86–1.35)
7b. Sodium	2,971	1.14 (0.83–1.56)	1.18 (0.86–1.61)

^a Analyses are performed using a Cox regression model adjusted for sex, age, and smoking status. Models evaluating score components and subcomponents are not mutually adjusted for each other. All results in italics are statistically significant

^b This analysis included a total of 480 incident obesity-related cancers

Table 4

Age and multivariable-adjusted^a Hazard Ratios (95 % CI) for breast, prostate, and colon cancers per unit of the total score and its components from exam 5 in 1991

	Breast cancer (n = 124)		Prostate cancer (n = 153)		Colorectal cancer (n = 63)	
	Age-adjusted HR (95 % CI)	Multivariable-adjusted ^{a,d} HR (95 % CI)	Age-adjusted HR (95 % CI)	Multivariable-adjusted ^{b,d} HR (95 % CI)	Age-adjusted HR (95 % CI)	Multivariable-adjusted ^{c,d} HR (95 % CI)
Total score	0.87 (0.73–1.03)	0.87 (0.74–1.03)	1.08 (0.92–1.27)	1.08 (0.92–1.27)	0.80 (0.64–1.01)	0.87 (0.68–1.12)
1. Body fitness	0.93 (0.60–1.45)	0.91 (0.59–1.42)	1.49 (0.94–2.36)	1.52 (0.95–2.42)	0.77 (0.40–1.48)	0.80 (0.40–1.57)
2. Physical activity	0.65 (0.39–1.07)	0.64 (0.39–1.07)	2.29 (1.33–3.95)	2.29 (1.33–3.95)	0.88 (0.43–1.78)	0.95 (0.47–1.93)
3. Foods that promote weight gain	1.23 (0.68–2.20)	1.25 (0.69–2.24)	0.86 (0.52–1.44)	0.86 (0.51–1.44)	1.04 (0.47–2.31)	1.16 (0.52–2.59)
3a. Energy-dense foods	1.27 (0.81–1.98)	1.26 (0.81–1.97)	0.91 (0.61–1.36)	0.93 (0.62–1.38)	1.17 (0.64–2.16)	1.27 (0.68–2.35)
3b. Sugary drinks	1.00 (0.65–1.55)	1.02 (0.66–1.58)	0.90 (0.60–1.34)	0.90 (0.60–1.35)	0.90 (0.49–1.65)	0.94 (0.51–1.73)
4. Plant foods	0.72 (0.35–1.48)	0.74 (0.36–1.53)	2.27 (1.19–4.35)	2.26 (1.18–4.35)	0.75 (0.27–2.07)	1.09 (0.39–3.05)
4a. Fruits and vegetables	0.61 (0.37–1.02)	0.62 (0.37–1.04)	1.83 (1.19–2.82)	1.84 (1.19–2.85)	0.74 (0.37–1.48)	0.96 (0.48–1.94)
4b. Refined grains	1.22 (0.78–1.91)	1.23 (0.78–1.92)	1.05 (0.71–1.56)	1.06 (0.71–1.56)	1.60 (0.86–2.96)	1.62 (0.88–2.99)
4c. Non-starchy and starchy vegetables	0.73 (0.48–1.12)	0.74 (0.48–1.12)	1.37 (0.94–2.00)	1.36 (0.93–1.98)	0.37 (0.19–0.74)	0.44 (0.22–0.88)
5. Animal foods	0.91 (0.54–1.52)	0.92 (0.55–1.55)	1.15 (0.72–1.84)	1.13 (0.70–1.81)	0.42 (0.20–0.87)	0.57 (0.27–1.21)
6. Alcohol	0.51 (0.30–0.89)	0.51 (0.29–0.89)	0.48 (0.28–0.81)	0.45 (0.26–0.77)	0.24 (0.12–0.45)	0.29 (0.15–0.56)
7. Preservation, processing and preparation	0.97 (0.52–1.80)	0.97 (0.52–1.80)	0.91 (0.56–1.48)	0.90 (0.55–1.48)	2.36 (0.94–5.89)	2.56 (1.02–6.40)
7a. Salty foods	0.87 (0.56–1.36)	0.87 (0.56–1.36)	0.90 (0.61–1.34)	0.90 (0.60–1.33)	1.71 (0.89–3.26)	1.79 (0.93–3.42)
7b. Sodium	1.06 (0.56–2.01)	1.06 (0.56–2.01)	1.30 (0.75–2.23)	1.29 (0.75–2.23)	3.21 (1.10–9.35)	3.50 (1.20–10.26)

^aAnalyses are performed using a Cox regression model adjusted for age and smoking status. Additional adjustment for menopausal status and hormone replacement therapy use did not change the results

^bAnalyses are performed using a Cox regression model adjusted for age and smoking status

^cAnalyses are performed using a Cox regression model adjusted for age, sex, and smoking status

^dModels evaluating score components and subcomponents are not mutually adjusted for each other