HHS Public Access

Author manuscript

Int J Cancer. Author manuscript; available in PMC 2016 November 15.

Published in final edited form as:

Int J Cancer. 2015 November 15; 137(10): 2413–2423. doi:10.1002/ijc.29600.

Adolescent and mid-life diet and subsequent risk of thyroid cancer in the NIH-AARP Diet and Health Study

Melissa Z. Braganza[1], **Nancy Potischman**[2], **Yikyung Park**[1,3], **Frances E. Thompson**[2], **Albert R. Hollenbeck**[4], and **Cari M. Kitahara**[1]

[1]Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, 9609 Medical Center Drive, Bethesda, MD 20892

[2]Division of Cancer Control and Population Sciences, National Cancer Institute, National Institutes of Health, 9609 Medical Center Drive, Bethesda, MD 20892

[3]Division of Public Health Sciences, Washington University School of Medicine, 660 S. Euclid Ave. St. Louis, MO 63110

[4]AARP Research (Retired), AARP, 601 E. Street NW, Washington, DC 20049

Abstract

Although thyroid cancer is suspected to have a nutritional etiology, prospective studies examining the relationship between diet and thyroid cancer are lacking. During 1996–1997, NIH-AARP Diet and Health Study participants, ages 51–72 years, completed a 37-item food frequency questionnaire about diet at ages 12–13 years (adolescence) and 10 years before baseline (mid-life). Over a median 10 years of follow-up, 325 individuals (143 men and 182 women) were diagnosed with thyroid cancer. Multivariable-adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) were calculated for intakes of foods and food groups comparing the highest to the lowest quartiles. Adolescent intakes of chicken/turkey (HR=1.59, 95% CI: 0.97–2.60; P_{trend}<0.01) and sweet baked goods (HR=1.59, 95% CI: 1.09–2.34; P_{trend} =0.04) were positively associated with thyroid cancer risk, while intake of butter/margarine was inversely associated with risk (HR=0.64, 95% CI: 0.44–0.91; P_{trend}<0.02). Similar to adolescent diet, mid-life intake of sweet baked goods was non-significantly associated with an increased risk of thyroid cancer (HR=1.39, 95% CI: 0.96–2.00; P_{trend} =0.11), but intake of butter/margarine was inversely associated with risk (HR=0.66, 95% CI: 0.46–0.95; P_{trend}=0.03). Among men, higher adolescent consumption of canned tuna was positively associated with risk of thyroid cancer (HR=1.69, 95% CI: 1.01–2.83; P_{trend}=0.03), and greater mid-life intake of broccoli was associated with a twofold increased risk (HR=2.13, 95% CI: 1.13–3.99; P_{trend} <0.01). This large prospective study suggests that several components of the adolescent and mid-life diet, including iodine-rich foods and goitrogens, may influence thyroid cancer risk.

Address for correspondence and reprints: Cari M. Kitahara, PhD, Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, 9609 Medical Center Drive, Bethesda, MD 20892, meinholdc@mail.nih.gov, Phone: 240-276-7406, Fax: 240-276-7874.

Keywords

adolescence; diet; nutrients; prospective study; thyroid cancer

Introduction

Although the carcinogenic effects of childhood and adolescent radiation exposure are known to persist for more than 50 years (1), few other potentially modifiable risk factors for thyroid cancer have been identified. While it has long been suspected that thyroid cancer has a nutritional etiology (2), the specific components of the diet that may influence risk are not well-characterized. *In vitro* and animal studies have demonstrated a link between several dietary factors and thyroid cancer, including iodine (3), goitrogens (4), fat (5), and flavonoids (6); however, epidemiologic evidence, based almost entirely on ecological and case-control studies, remains limited and inconsistent (7, 8). Prospective studies, which avoid biases due to differential recall and post-diagnostic dietary changes, are currently lacking but are essential for improving our understanding of the role of diet in thyroid cancer development.

Although the epidemiologic evidence on thyroid cancer is centered on risk factors related to adulthood, diet several decades before diagnosis could influence carcinogenesis. Adult thyroid cancer is diagnosed at relatively young ages compared with other malignancies (2), suggesting that early life may be an etiologically relevant time period. Adolescence may be a particularly sensitive period for epigenetic modification because the thyroid gland is continuing to grow and develop (9–12). Several observational studies have reported associations between recalled adolescent diet and risk of adult breast, colorectal, and pancreatic cancers (13), but no study, to our knowledge, has comprehensively investigated adolescent diet in relation to risk of thyroid cancer.

We prospectively investigated adolescent and mid-life intakes of foods and food groups in relation to thyroid cancer risk using data from more than 290,000 participants in the NIH-AARP Diet and Health Study. As a secondary analysis, we also examined associations for estimated intakes of select macronutrients, micronutrients, and fiber.

Materials and Methods

Study population

The NIH-AARP Diet and Health Study was established when AARP members, between the ages of 50 and 71 years, who resided in the states of California, Florida, Louisiana, Pennsylvania, New Jersey, and North Carolina and the metropolitan areas of Atlanta, Georgia, and Detroit, Michigan, responded to a mailed questionnaire, which ascertained information on demographics, medical history, and various lifestyle characteristics (14). Six months later, 334,905 of the initial respondents completed a second questionnaire, the risk factor questionnaire (RFQ), which elicited information on diet at ages 12–13 years and 10 years before baseline (when respondents were 41–62 years of age) as well as other factors (e.g., medication use, menopausal hormone therapy, weight and physical activity over the life course). After excluding proxy respondents (n=10,383), individuals with a self-reported cancer diagnosis at administration of the baseline questionnaire (n=14,565) or RFQ (n=4,298), cancer cases that were identified only through death records (n=1,293), individuals with 0 person-years of follow-up (n=47), participants with 0 or missing total energy intake as assessed by the baseline food frequency questionnaire (n=8,914), and respondents reporting extreme energy intakes (i.e., more than twice the interquartile range of the Box-Cox logarithmic-transformed scale for diet in the previous 12 months) (n=2,333) or at ages 12–13 years (n=595), our study population consisted of 292,477 individuals: 170,975 men and 121,502 women. All participants provided informed consent by virtue of returning a questionnaire, and the study was approved by the Special Studies Institutional Review Board of the U.S. National Cancer Institute.

Exposure Assessment

The RFQ elicited information on consumption of 37 food items, which represent important sources of vitamin A, vitamin C, fat, and fiber, at ages 12–13 years (1937–1957) and 10 years prior to completion of the RFQ (1986–1987) (15). Identical food frequency questionnaires were used to assess diet for these two unique time periods, facilitating comparisons between the influence of adolescent and mid-life diet on risk of thyroid cancer. Participants were asked to categorize their frequency of intake of each food item: never, 1–11 times per year, 1–3 times per month, 1–2 times per week, 3–4 times per week, 5–6 times per week, 1 time per day, 2 or more times per day. Since food portion sizes were not assessed, data from the U.S. Department of Agriculture 1965–1966 Household Food Consumption Survey (HFCS) on adolescents, ages 12–13 years, were used to assign sex-specific portion sizes in order to estimate macro- and micro-nutrient intakes. The 1965–1966 HFCS was the first nationwide survey of individual food consumption, and these data were collected closest in time to our period of interest (1937–1957). The median sex-specific serving size was multiplied by the nutrient value per 100 g-serving, and subsequently, multiplied by the frequency of intake. For the “2 or more times per day” category, the median frequency was determined from the HFCS data. Similarly, macro- and micro-nutrient intakes 10 years before baseline were calculated using data from NHANES III 1988–1994 (16). Fiber intake for both time periods was calculated based on data from NHANES 1999–2000.

Food groups (grains, vegetables, fruit, dairy, chicken and/or turkey, red meat, canned tuna, butter and/or margarine, and sweet baked goods) were created from individual food items assessed on the RFQ. Cruciferous vegetables were of particular interest for thyroid cancer because goitrogens have been implicated in thyroid tumorigenesis (4); thus we separately examined the only source of this constituent on the RFQ: broccoli. Nutrient intakes (carbohydrates, total fat, protein, fiber, calcium, vitamin A, and vitamin C) were adjusted for total energy intake using the nutrient density method (17). Intakes of food groups and nutrients were divided into quartiles based on the overall study population with the lowest category of consumption being the referent group. Analyses of follicular carcinoma required tertiles of intake due to the smaller number of cases (n=60). Any categories with fewer than 10 cases were combined.

Outcome and Follow-Up

Cancer outcomes were ascertained through probabilistic linkage to ten state cancer registries (14). Matching of study participants to cancer registries identified approximately 90% of all cancer cases (18). Cases were defined as individuals diagnosed with a first primary thyroid cancer during the follow-up period and were further classified according to histological subtype: papillary carcinoma (ICD-O-2 histological codes: 8050, 8260, 8340–8344, 8350, 8450–8460) and follicular carcinoma (histological codes: 8290, 8330–8335) (19). Study participants were followed starting on the date of RFQ completion and were censored at the first occurrence of one of the following events: cancer diagnosis (excluding non-melanoma skin cancer), death, emigration out of the cancer registry area, or the follow-up end date (December 31, 2006).

Statistical analysis

Hazard ratios (HRs) and 95% confidence intervals (CIs) were generated using Cox proportional hazard models with attained age as the underlying time metric. Models were adjusted for sex, education, race/ethnicity, and total energy intake at ages 12–13 years (adolescence) or 10 years before baseline (mid-life). The inclusion of additional potential confounders (family history of cancer, BMI at age 18, current BMI, cigarette smoking status, alcohol intake, use of oral contraceptives, menopausal hormone therapy use) did not change any of the HRs by more than 10%, and thus these variables were not retained in the final models. We additionally investigated risk according to sex because incidence of thyroid cancer is 2–4 times higher in women than men (2), and it is unclear whether this sex difference reflects physiological differences or differences in lifestyle-related factors. Multiplicative interactions for sex were tested by comparing the fit of a model including the cross-product term with a model not including this term using the likelihood ratio test.

Tests for linear trend were performed by assigning a numerical value to each category (e.g., 1, 2, 3) and modeling this categorical variable as continuous. Spearman coefficients were used to evaluate correlations between adolescent and mid-life intakes. All statistical analyses were performed using Stata 11.2 (Stata Corporation, College Station, TX).

Results

Table 1 describes the demographic, anthropometric, and lifestyle characteristics of study participants. Over a median 10 years of follow-up, 143 men and 182 women were diagnosed with first primary thyroid cancer. The majority of these 325 cases were papillary (n=240) and follicular (n=60) carcinomas. The median age at thyroid cancer diagnosis was 68.6 years.

We observed several associations for the highest versus lowest quartiles of self-reported adolescent and mid-life intakes of specific food groups with thyroid cancer risk in the overall population (men and women combined) (Table 2). Adolescent intakes of chicken/turkey (HR=1.59, 95% CI: 0.97–2.60; P_{trend}<0.01) and sweet baked goods (HR=1.59, 95% CI: 1.09–2.34; P_{trend} =0.04) were positively associated with thyroid cancer risk, but adolescent intake of butter/margarine was inversely associated with risk (HR=0.64, 95% CI:

0.44–0.91; P_{trend} =0.02). Similar to adolescent diet, mid-life consumption of butter/ margarine was inversely associated with risk of thyroid cancer (HR=0.66, 95% CI: 0.46–0.95; P_{trend}=0.03), and greater mid-life intake of sweet baked goods was non-significantly positively associated with risk (HR=1.39, 95% CI: 0.96–2.00; P_{trend}=0.11). Adolescent and mid-life intakes for butter/ (HR=1.62, 95% CI: 1.00–2.62; P_{trend}=0.07) and mid-life (HR=1.87, 95% CI: 1.14–3.06; P_{trend}=0.02) were associated with increased risk of thyroid cancer. Non-significant associations were observed for women with the highest versus lowest quartile of chicken/turkey intake in adolescence (HR=1.47, 95% CI: 0.78–2.76; P_{trend}=0.06), butter/margarine intake in adolescence (HR=0.61, 95% CI: 0.38–0.98; P_{trend}=0.06), and vegetable intake in both adolescence (HR=0.64, 95% CI: 0.40–1.01; P_{trend}=0.08) and mid-life (HR=0.68, 95% CI: 0.43–1.06; P_{trend}=0.05). The associations for vegetable intake during adolescence and mid-life were, respectively, significantly (P=0.02) and borderline-significantly (P=0.06) modified by sex. We found only moderate correlations between adolescent and mid-cancer later in life. Fewer associations emerged for mid-life diet, but we did observe a positive association for broccoli intake among men.

Due to the importance of iodine in the synthesis of thyroid hormones and epidemiologic evidence linking iodine deficiency with certain benign thyroid diseases (2), dietary iodine has long been suspected to play a role in thyroid carcinogenesis. Early ecological studies suggested that high iodine intake is associated with an increased risk of papillary carcinoma, while iodine deficiency is associated with a higher risk of follicular carcinoma (2); however, these results have not been consistently replicated in recent case-control studies (7, 8). Historically, most observational studies have used fish and shellfish intake as proxies for dietary iodine exposure (7, 8), but dairy products and cooked turkey breast have also been found to contain higher levels of iodine in the U.S. (20). In this study, intakes of canned tuna and chicken/turkey were positively associated with risk of thyroid cancer, but intake of dairy was not. Results from the only two studies investigating dietary intake of iodine during childhood or adolescence suggest that greater iodine intake is associated with a reduced risk of thyroid cancer (21, 22), but each of these studies directly assessed only one aspect of dietary iodine intake. Mack et al. observed a reduced risk of thyroid cancer among women reporting higher childhood consumption of shellfish (21), but this association was based on only three exposed cases. In another population-based case-control study, intake of iodized salt, compared to non-iodized or unspecified salt, at age 15 was associated with a decreased risk of thyroid cancer (22). Previous studies on radiation exposure during childhood and adolescence indicate that early-life may be a particularly sensitive exposure period in thyroid cancer development (23). Studies have shown that specific chromosomal rearrangements (e.g., *RET/PTC*) are highly prevalent among individuals diagnosed with papillary carcinoma after accidental or therapeutic radiation exposure during childhood or adolescence (9). Similar to the association that has been observed previously between specific chromosomal rearrangements and radiation exposure (9), a higher prevalence of *BRAF* mutations among individuals diagnosed with papillary carcinoma has been linked with higher iodine content in drinking water (24). Like radiation, iodine may play a role in initiating thyroid carcinogenesis by inducing genetic alterations.

Cruciferous vegetables contain goitrogens that can block iodine uptake by the thyroid and have been shown to promote thyroid carcinogenesis in rats (4); however, results from epidemiologic studies on the relationship between cruciferous vegetables and thyroid cancer risk have been inconsistent (7). In the current study, we observed that higher mid-life intake of broccoli was positively associated with risk of thyroid cancer among men but not women. Because we lacked information on consumption of other cruciferous vegetables (e.g., cabbage, radish, etc.), the finding for broccoli should be interpreted cautiously.

Similar associations were observed for adolescent and mid-life intakes of butter/margarine and sweet baked goods. In light of an animal study demonstrating the thyroid tumor-promoting effects of obesity induced by a high-fat diet (5) and the positive associations for sweet baked goods in the current study, the inverse associations that we observed for consumption of butter/margarine are puzzling. Among women, vegetable intake was inversely associated with thyroid cancer risk for both time periods, and as with other cancers, these associations may reflect the protective effects of several vegetable components (e.g., flavonoids, anti-oxidants, phenols, folate), which are important in detoxification, anti-proliferation, and DNA synthesis and repair (6, 25).

The higher incidence of thyroid cancer in women compared with men may reflect, in part, an influence of dietary, environmental, and/or physiological factors in the etiology of this malignancy. In this study, stratified analyses showed differences in associations for certain foods between men and women. This may reflect differences in how men and women complete food frequency questionnaires (26, 27), different ranges of dietary intakes between men and women, or physiological differences.

The large size of the study cohort, the prospective study design, and the availability of data on diet at more than one point during the life course are major strengths of our study. The relatively large number of thyroid cancer cases allowed for a comprehensive investigation of risk according to sex and histological subtype across a range of dietary intakes. The RFQ assessed identical components of the adolescent and mid-life diet, enabling us to compare the unique influence of various dietary factors on thyroid cancer risk for each time period.

As with most other cancer studies that have investigated adolescent diet, the accuracy of recalled exposure information is a potential limitation. Adult recall of adolescent diet through food frequency questionnaires has been shown to be practical (28), though validity is difficult to ascertain. The two food frequency questionnaires used in this study have not been validated. Reliability of recalled intakes may also vary by food. For example, in a case-control study that investigated recalled adolescent diet in relation to breast cancer risk among women, agreement between study participants and their mothers was higher for adolescent consumption of chicken than for whole-grain bread (29). To improve individual recall in the current study, each section of the RFQ began with orienting questions, such as place of residence at ages 12–13 years or 10 years ago, to help the participants focus on the time period of interest. Additionally, the food frequency questionnaire on diet 10 years before baseline also included introductory statements recapping specific historical events from that time period to help focus the participant's recall on the correct time period. We were unable to examine intake of some foods (e.g., cabbage, soy, etc.) that have been associated with other cancers, as these were not ascertained in the RFQ. The RFQ was designed to estimate intake of only four key nutrients (vitamin A, vitamin C, fat, and fiber) thought to be related to cancer, but it is not ideal for the calculation of total energy intake and other nutrient intakes, which may have been underestimated due to the limited number of foods assessed. Information on food portion sizes was estimated from outside sources close in time to the period of interest, which may have contributed to measurement error in intake that could have attenuated our results. The results presented were not corrected for the number of tests performed, and it is possible that some findings were due to solely to chance. Certain dietary factors, such as fruits and vegetables, may be associated with greater healthcare access and utilization and, thus, a greater likelihood of thyroid nodule detection (30, 31). Although our results are adjusted for some indicators of socioeconomic status, including race/ethnicity and education, residual confounding is possible. Information on method of thyroid cancer detection and/or diagnosis or tumor size, which would have been useful in distinguishing incidentally-detected versus clinically relevant tumors, was not available in the current study.

Adult cancers often have a long natural history, and determining the timing of risk factors in cancer etiology can aid in understanding the causal pathway for malignancies. Although there is growing evidence that early-life exposures (e.g., childhood and adolescent radiation exposure, adolescent height and BMI) may influence the development of adult thyroid cancer (10–12, 23), studies investigating the influence of childhood and adolescent diet on thyroid cancer risk are lacking. Our findings suggest that several components of the adolescent diet are associated with risk of thyroid cancer, providing further support that adolescence may be a particularly influential time period for thyroid carcinogenesis. Prospective studies with more detailed assessments of diet and other environmental exposures over the life course may provide further insight into the etiology of thyroid cancer.

Acknowledgments

This work was supported by the Intramural Research Program of the National Cancer Institute at the National Institutes of Health.

Abbreviations

HR	Hazard ratio
CI	Confidence interval
NIH-AARP	National Institutes of Health-American Association of Retired Persons
RFQ	Risk Factor Questionnaire

References

1. Furukawa K, Preston D, Funamoto S, et al. Long-term trend of thyroid cancer risk among Japanese atomic-bomb survivors: 60 years after exposure. Int J Cancer. 2013; 132(5):1222–1226. [PubMed: 22847218]

2. Ron, E.; Schneider, AB. Thyroid Cancer. In: Schottenfeld, D.; Fraumeni, JF., Jr, editors. Cancer Epidemiology and Prevention. Oxford: Oxford University Press; 2006. p. 975-994.
3. Ward JM, Ohshima M. The role of iodine in carcinogenesis. Advances in Experimental Medicine and Biology. 1986; 206:529–542. [PubMed: 3591538]
4. Kanno J, Matsuoka C, Furuta K, et al. Tumor promoting effect of goitrogens on the rat thyroid. Toxicologic Pathology. 1990; 18(2):239–246. [PubMed: 1697977]
5. Kim WG, Park JW, Willingham MC, et al. Diet-induced obesity increases tumor growth and promotes anaplastic change in thyroid cancer in a mouse model. Endocrinology. 2013; 154(8): 2936–2947. [PubMed: 23748362]
6. Yin F, Giuliano AE, Van Herle AJ. Growth inhibitory effects of flavonoids in human thyroid cancer cell lines. Thyroid. 1999; 9(4):369–376. [PubMed: 10319943]
7. Peterson E, De P, Nuttall R. BMI, diet and female reproductive factors as risks for thyroid cancer: a systematic review. PLOS ONE. 2012; 7(1):e29177. [PubMed: 22276106]
8. Dal Maso L, Bosetti C, La Vecchia C, et al. Risk factors for thyroid cancer: an epidemiological review focused on nutritional factors. Cancer Causes & Control. 2009; 20(1):75–86. [PubMed: 18766448]
9. Nikiforov YE, Nikiforova MN. Molecular genetics and diagnosis of thyroid cancer. Nature Reviews Endocrinology. 2011; 7(10):569–580.
10. Kitahara CM, Gamborg M, Berrington de Gonzalez A, et al. Childhood height and body mass index were associated with risk of adult thyroid cancer in a large cohort study. Cancer Research. 2014; 74(1):235–242. [PubMed: 24247722]
11. Kitahara CM, Platz EA, Freeman LE, et al. Obesity and thyroid cancer risk among U.S. men and women: a pooled analysis of five prospective studies. Cancer Epidemiology, Biomarkers & Prevention. 2011; 20(3):464–72.
12. Brindel P, Doyon F, Rachedi F, et al. Anthropometric factors in differentiated thyroid cancer in French Polynesia: a case-control study. Cancer Causes & Control. 2009; 20(5):581–590. [PubMed: 19043789]
13. Potischman N, Linet MS. Invited commentary: are dietary intakes and other exposures in childhood and adolescence important for adult cancers? American Journal of Epidemiology. 2013; 178(2):184–189. [PubMed: 23792894]
14. Schatzkin A, Subar AF, Thompson FE, et al. Design and serendipity in establishing a large cohort with wide dietary intake distributions : the National Institutes of Health-American Association of Retired Persons Diet and Health Study. American Journal of Epidemiology. 2001; 154(12):1119–1125. [PubMed: 11744517]
15. Ruder EH, Thiebaut AC, Thompson FE, et al. Adolescent and mid-life diet: risk of colorectal cancer in the NIH-AARP Diet and Health Study. The American Journal of Clinical Nutrition. 2011; 94(6):1607–1619. [PubMed: 22071715]
16. Centers for Disease Control and Prevention (CDC). Third National Health and Nutrition Examination Survey (NHANES III). 2009. Version current 30 March 2011. Available from: http://www.cdc.gov/nchs/nhanes/nh3data.htm (cited 27 July 2014)
17. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. The American Journal of Clinical Nutrition. 1997; 65(4 Suppl):1220S–8S. discussion 9S–31S. [PubMed: 9094926]
18. Michaud D, Midthune D, Hermansen S, et al. Comparison of Cancer Registry Case Ascertainment with SEER Estimates and Self-reporting in a Subset of the NIH-AARP Diet and Health Study. Journal of Registry Management. 2005; 32(2):70–75.
19. Cancer incidence in five continents. IARC Scientific Publications. 2008; IX(160):1–837.
20. Pennington JAT, Schoen SA, Salmon GD, et al. Composition of Core Foods of the U.S. Food Supply, 1982–1991. Journal of Food Composition and Analysis. 1995; 8:171–217.
21. Mack WJ, Preston-Martin S, Bernstein L, et al. Lifestyle and other risk factors for thyroid cancer in Los Angeles County females. Annals of Epidemiology. 2002; 12(6):395–401. [PubMed: 12160598]

22. Galanti MR, Hansson L, Bergstrom R, et al. Diet and the risk of papillary and follicular thyroid carcinoma: a population-based case-control study in Sweden and Norway. Cancer Causes & Control. 1997; 8(2):205–214. [PubMed: 9134245]
23. Ron E, Lubin JH, Shore RE, et al. Thyroid cancer after exposure to external radiation: a pooled analysis of seven studies. Radiation Research. 1995; 141(3):259–77. [PubMed: 7871153]
24. Guan H, Ji M, Bao R, et al. Association of high iodine intake with the T1799A BRAF mutation in papillary thyroid cancer. The Journal of Clinical Endocrinology and Metabolism. 2009; 94(5): 1612–1617. [PubMed: 19190105]
25. World Cancer Research Fund/American Institute for Cancer Research. Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective. Washington DC: AICR; 2007.
26. Subar AF, Kipnis V, Troiano RP, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. American Journal of Epidemiology. 2003; 158(1):1–13. [PubMed: 12835280]
27. Kipnis V, Subar AF, Midthune D, et al. Structure of dietary measurement error: results of the OPEN biomarker study. American Journal of Epidemiology. 2003; 158(1):14–21. discussion 2–6. [PubMed: 12835281]
28. Maruti SS, Feskanich D, Colditz GA, et al. Adult recall of adolescent diet: reproducibility and comparison with maternal reporting. American Journal of Epidemiology. 2005; 161(1):89–97. [PubMed: 15615919]
29. Potischman N, Weiss HA, Swanson CA, et al. Diet during adolescence and risk of breast cancer among young women. J Natl Cancer Inst. 1998; 90(3):226–233. [PubMed: 9462680]
30. Irala-Estévez JD, Groth M, Johansson L, Oltersdorf U, Prättälä R, Martínez-González MA. A systematic review of socio-economic differences in food habits in Europe: consumption of fruit and vegetables. Eur J Clin Nutr. 2000; 54(9):706–714. [PubMed: 11002383]
31. Pearson N, Biddle SJ, Gorely T. Family correlates of fruit and vegetable consumption in children and adolescents: a systematic review. Public Health Nutr. 2009; 12(2):267–283. [PubMed: 18559129]

Author Manuscript

Author Manuscript

Author Manuscript

Impact Statement

This large prospective study suggests that several components of the adolescent and mid-life diet, including iodine-rich foods and goitrogens, are associated with an increased risk of thyroid cancer, providing further support that adolescence may be a particularly influential time period for thyroid carcinogenesis.

Table 1

Baseline Characteristics of U.S. Men and Women in the NIH-AARP Diet and Health Study Cohort, 1996–2006

	Overall Cohort	Men	Women
Study participants	292,477	170,975	121,502
Age at RFQ completion, years (median)	63.4	63.7	63.1
Race/ethnicity (%)			
Non-Hispanic White	93	94	91
Non-Hispanic Black	3	2	5
Hispanic/Other	3	3	3
Missing	1	1	1
Education (%)			
<High school	5	5	5
High school graduate	52	45	60
College graduate	42	48	32
Missing	2	2	3
Body mass index (%)			
<25 kg/m^2	36	31	45
25–29.9 kg/m^2	41	48	31
• ‰• •^{2}	20	20	21
Missing	2	1	3
Family history of cancer (%)			
No	46	47	44
Yes	50	48	52
Missing	5	5	4
Cigarette smoking status (%)			
Never smoked	36	30	44
Former smoker	50	57	39
Current smoker	11	9	13
Missing	3	3	3
Alcohol intake (%)			
None	23	20	28
<1 drink per day	53	50	59
1–2 drinks per day	12	15	9
>2 drinks per day	11	16	5
Oral contraceptive use (%)			
Never (or <1 year)			59
1–4 years			17
5–9 years			12

Table 2

Hazard ratios (HRs) and 95% Confidence Intervals (CIs) for Thyroid Cancer and Intake of Select Food Groups at Ages 12–13 Years and 10 Years Before Baseline

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	**Cases**	**HR (95% CI)[a]**	**Median (frequency/day)**	**Cases**	**HR (95% CI)[b]**
Grains[c]						
Quartile 1	0.44	87	1.00 (reference)	0.30	91	1.00 (reference)
Quartile 2	0.80	106	0.86 (0.64–1.16)	0.73	73	0.72 (0.52–1.00)
Quartile 3	1.02	54	0.79 (0.55–1.14)	1.03	83	0.99 (0.71–1.39)
Quartile 4	2.02	78	0.77 (0.54–1.09)	2.02	76	0.76 (0.52–1.10)
P-trend[d]			0.14			0.41
Vegetables[e]						
Quartile 1	0.57	80	1.00 (reference)	0.66	76	1.00 (reference)
Quartile 2	1.14	80	0.94 (0.69–1.29)	1.28	94	1.17 (0.86–1.59)
Quartile 3	1.70	87	0.97 (0.70–1.34)	1.90	74	0.92 (0.66–1.29)
Quartile 4	2.65	78	0.84 (0.59–1.19)	2.85	79	0.90 (0.64–1.27)
P-trend[d]			0.37			0.29
Fruit[f]						
Quartile 1	0.15	80	1.00 (reference)	0.21	78	1.00 (reference)
Quartile 2	0.52	70	0.97 (0.70–1.35)	0.71	83	1.07 (0.79–1.47)
Quartile 3	1.08	88	1.05 (0.76–1.46)	1.21	80	1.03 (0.75–1.42)
Quartile 4	2.00	87	1.09 (0.77–1.55)	2.02	82	0.96 (0.69–1.33)
P-trend[d]			0.55			0.74
Dairy[g]						
Quartile 1	0.58	82	1.00 (reference)	0.38	76	1.00 (reference)
Quartile 2	1.21	70	0.83 (0.59–1.17)	0.99	70	0.95 (0.68–1.34)
Quartile 3	2.21	89	1.07 (0.73–1.56)	1.44	90	1.25 (0.88–1.77)
Quartile 4	3.71	84	1.32 (0.85–2.06)	2.46	87	1.17 (0.80–1.71)
P-trend[d]			0.17			0.24

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	**Cases**	**HR (95% CI)[a]**	**Median (frequency/day)**	**Cases**	**HR (95% CI)[b]**
Chicken and turkey[h]						
Quartile 1	0–0.03	27	1.00 (reference)	0–0.03	14	1.00 (reference)
Quartile 2	0.04–0.13	76	1.03 (0.66–1.60)	0.04–0.13	80	1.50 (0.85–2.65)
Quartile 3	0.14–0.41	171	1.39 (0.91–2.12)	0.14–0.41	166	1.44 (0.83–2.50)
Quartile 4	0.42	51	1.59 (0.97–2.60)	0.42	63	1.33 (0.74–2.40)
P-trend[d]			<0.01			0.85
Red meat[i]						
Quartile 1	0.36	86	1.00 (reference)	0.18	96	1.00 (reference)
Quartile 2	0.78	87	1.25 (0.92–1.71)	0.51	80	0.86 (0.64–1.17)
Quartile 3	1.21	85	1.03 (0.74–1.45)	0.86	77	0.80 (0.57–1.10)
Quartile 4	1.92	67	0.91 (0.61–1.36)	1.36	70	0.78 (0.54–1.14)
P-trend[d]			0.53			0.17
Canned tuna[h]						
Quartile 1	0	79	1.00 (reference)	0	26	1.00 (reference)
Quartile 2	0.01–0.03	66	1.12 (0.80–1.55)	0.01–0.03	84	1.08 (0.70–1.68)
Quartile 3	0.04–0.13	101	1.28 (0.94–1.72)	0.04–0.13	114	0.80 (0.52–1.23)
Quartile 4						
Quartile 3	1.00	85	0.81 (0.59–1.12)	0.85	73	0.99 (0.71–1.38)
Quartile 4	2.00	71	0.64 (0.44–0.91)	2.00	64	0.66 (0.46–0.95)
P-trend[d]			0.02			0.03
Sweet baked goods[j]						
Quartile 1	0.13	76	1.00 (reference)	0.07	80	1.00 (reference)
Quartile 2	0.44	78	1.10 (0.79–1.52)	0.25	78	1.31 (0.95–1.79)
Quartile 3	0.78	86	1.06 (0.75–1.49)	0.58	76	1.24 (0.89–1.74)
Quartile 4	1.57	85	1.59 (1.09–2.34)	1.21	89	1.39 (0.96–2.00)
P-trend[d]			0.04			0.11

CI – Confidence Interval; HR – Hazard Ratio

[a]Adjusted for total energy intake at ages 12–13 years, sex, race/ethnicity, and education with age as the underlying time metric

[b] Adjusted for total energy intake 10 years before baseline, sex, race/ethnicity, and education with age as the underlying time metric

[c] White bread or rolls and dark bread or rolls (rye, whole grain, whole wheat, pumpernickel)

[d] P-trend calculated by modeling the categorical variable as continuous

[e] Broccoli, carrots, lettuce salads, fresh tomatoes, tomato or vegetable soup, beans (such as baked beans, refried beans, pintos, kidney, or limas), and other vegetables (such as corn, peas, and green beans)

[f] Fresh, uncooked apples, orange or grapefruit juice, oranges, grapefruit, tangerines, and canned fruits (such as peaches, pears, and applesauce)

[g] Whole and low-fat milks, cheese and cheese spreads, pizza, and ice cream and milk shakes

[h] Due to clustering at specific intakes, categories were assigned

[i] Bacon, sausage, cold cuts/luncheon meats (such as ham, bologna, salami, corned beef, or pastrami), hotdogs/frankfurters, ground beef (in hamburgers, meatloaf, meatballs, or casseroles), roast beef, and steak

[j] Cookies, brownies, cake, donuts, sweet rolls, danish, sweet muffins, and dessert breads

Table 3

Hazard ratios (HRs) and 95% Confidence Intervals (CIs) for Thyroid Cancer and Intake of Select Food Groups at Ages 12–13 Years and 10 Years Before Baseline in Men

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	**Cases**	**HR (95% CI)[a]**	**Median (frequency/day)**	**Cases**	**HR (95% CI)[b]**
Grains[c]						
Quartile 1	0.44	37	1.00 (reference)	0.30	29	1.00 (reference)
Quartile 2	0.80	44	0.84 (0.53–1.33)	0.73	37	1.08 (0.65–1.80)
Quartile 3	1.02	26	0.85 (0.49–1.47)	1.03	44	1.55 (0.91–2.65)
Quartile 4	2.02	36	0.86 (0.51–1.47)	2.02	32	0.91 (0.49–1.69)
P-trend[d]			0.68			0.95
Vegetables[e]						
Quartile 1	0.56	32	1.00 (reference)	0.63	30	1.00 (reference)
Quartile 2	1.09	36	1.12 (0.69–1.83)	1.20	44	1.46 (0.91–2.34)
Quartile 3	1.63	38	1.16 (0.70–1.92)	1.77	32	1.14 (0.68–1.91)
Quartile 4	2.57	37	1.21 (0.71–2.07)	2.72	36	1.31 (0.78–2.21)
P-trend[d]			0.49			0.55
Fruit[f]						
Quartile 1	0.15	36	1.00 (reference)	0.20	36	1.00 (reference)
Quartile 2	0.46	35	1.04 (0.65–1.69)	0.66	37	1.03 (0.65–1.64)
Quartile 3	0.94	39	1.11 (0.68–1.81)	1.15	29	0.78 (0.47–1.30)
Quartile 4	1.71	33	1.28 (0.74–2.20)	1.93	40	1.16 (0.72–1.88)
P-trend[d]			0.38			0.79
Dairy[g]						
Quartile 1	0.63	31	1.00 (reference)	0.43	30	1.00 (reference)
Quartile 2	1.21	32	0.94 (0.55–1.60)	1.01	29	0.88 (0.52–1.49)
Quartile 3	2.02	41	1.44 (0.79–2.63)	1.44	46	1.34 (0.79–2.27)
Quartile 4	3.71	39	1.65 (0.82–3.30)	2.37	37	1.08 (0.59–1.95)
P-trend[d]			0.11			0.52

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	**Cases**	**HR (95% CI)[a]**	**Median (frequency/day)**	**Cases**	**HR (95% CI)[b]**
Chicken and turkey[h]						
Quartile 1	0–0.03	11	1.00 (reference)	0–0.13	39	1.00 (reference)
Quartile 2	0.04–0.13	37	1.16 (0.59–2.29)			
Quartile 3	0.14–0.41	75	1.52 (0.79–2.93)	0.14–0.41	79	1.24 (0.84–1.84)
Quartile 4	0.42	20	1.77 (0.81–3.85)	0.42	24	1.12 (0.66–1.91)
P-trend[d]			0.07			0.55
Red meat[i]						
Quartile 1	0.43	28	1.00 (reference)	0.23	34	1.00 (reference)
Quartile 2	0.86	42	1.69 (1.02–2.82)	0.58	33	0.86 (0.53–1.41)
Quartile 3	1.30	33	1.05 (0.59–1.86)	0.92	32	0.69 (0.41–1.17)
Quartile 4	1.93	40	1.27 (0.68–2.39)	1.49	43	0.82 (0.47–1.43)
P-trend[d]			0.89			0.38
Canned tuna[h]						
Quartile 1	0	29	1.00 (reference)	0	17	1.00 (reference)
Quartile 2	0.01–0.03	32	1.49 (0.90–2.46)	0.01–0.03	34	0.78 (0.44–1.40)
Quartile 3	0.04–0.13	46	1.69 (1.05–2.71)	0.04–0.13	54	0.77 (0.44–1.33)
Quartile 4						
Quartile 1	0.21	39	1.00 (reference)	0.08	47	1.00 (reference)
Quartile 2	0.79	42	1.00 (0.63–1.58)	0.50	47	0.87 (0.57–1.32)
Quartile 3	1.00	35	0.84 (0.51–1.39)	0.80	21	0.54 (0.31–0.93)
Quartile 4	2.00	27	0.65 (0.37–1.16)	1.57	27	0.56 (0.33–0.96)
P-trend[d]			0.12			0.01
Sweet baked goods[j]						
Quartile 1	0.13	27	1.00 (reference)	0.08	39	1.00 (reference)
Quartile 2	0.44	43	1.56 (0.95–2.58)	0.30	28	0.86 (0.52–1.41)
Quartile 3	0.78	39	1.21 (0.70–2.10)	0.63	34	0.93 (0.56–1.53)
Quartile 4	1.50	34	1.58 (0.85–2.93)	1.21	41	0.93 (0.54–1.60)
P-trend[d]			0.32			0.84

CI – Confidence Interval; HR – Hazard Ratio

[a] Adjusted for total energy intake at ages 12–13 years, race/ethnicity, and education with age as the underlying time metric

[b] Adjusted for total energy intake 10 years before baseline, race/ethnicity, and education with age as the underlying time metric

[c] White bread or rolls and dark bread or rolls (rye, whole grain, whole wheat, pumpernickel)

[d] P-trend calculated by modeling the categorical variable as continuous

[e] Broccoli, carrots, lettuce salads, fresh tomatoes, tomato or vegetable soup, beans (such as baked beans, refried beans, pintos, kidney, or limas), and other vegetables (such as corn, peas, and green beans)

[f] Fresh, uncooked apples, orange or grapefruit juice, oranges, grapefruit, tangerines, and canned fruits (such as peaches, pears, and applesauce)

[g] Whole and low-fat milks, cheese and cheese spreads, pizza, and ice cream and milk shakes

[h] Due to clustering at specific intakes, categories were assigned

[i] Bacon, sausage, cold cuts/luncheon meats (such as ham, bologna, salami, corned beef, or pastrami), hotdogs/frankfurters, ground beef (in hamburgers, meatloaf, meatballs, or casseroles), roast beef, and steak

[j] Cookies, brownies, cake, donuts, sweet rolls, danish, sweet muffins, and dessert breads

Table 4

Hazard ratios (HRs) and 95% Confidence Intervals (CIs) for Thyroid Cancer and Intake of Select Food Groups at Ages 12–13 Years and 10 Years Before Baseline in Women

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	Cases	HR (95% CI)[a]	Median (frequency/day)	Cases	HR (95% CI)[b]
Grains[c]						
Quartile 1	0.43	50	1.00 (reference)	0.25	62	1.00 (reference)
Quartile 2	0.80	62	0.88 (0.59–1.30)	0.63	36	0.55 (0.36–0.85)
Quartile 3	1.02	28	0.73 (0.44–1.20)	1.02	39	0.72 (0.46–1.13)
Quartile 4	2.02	42	0.69 (0.43–1.11)	2.02	44	0.69 (0.43–1.12)
P-trend[d]			0.10			0.25
Vegetables[e]						
Quartile 1	0.61	48	1.00 (reference)	0.71	46	1.00 (reference)
Quartile 2	1.20	44	0.83 (0.54–1.26)	1.36	50	0.97 (0.64–1.46)
Quartile 3	1.77	49	0.85 (0.56–1.29)	2.01	42	0.77 (0.50–1.19)
Quartile 4	2.80	41	0.64 (0.40–1.01)	3.01	43	0.68 (0.43–1.06)
P-trend[d]			0.08			0.05
Fruit[f]						
Quartile 1	0.16	44	1.00 (reference)	0.21	42	1.00 (reference)
Quartile 2	0.63	35	0.91 (0.58–1.43)	0.75	46	1.10 (0.72–1.69)
Quartile 3	1.23	49	1.00 (0.65–1.54)	1.28	51	1.24 (0.81–1.90)
Quartile 4	2.21	54	0.99 (0.63–1.55)	2.08	42	0.83 (0.52–1.30)
P-trend[d]			0.95			0.52
Dairy[g]						
Quartile 1	0.52	51	1.00 (reference)	0.36	46	1.00 (reference)
Quartile 2	1.21	38	0.77 (0.49–1.21)	0.96	41	1.02 (0.66–1.58)
Quartile 3	2.57	48	0.86 (0.52–1.41)	1.44	44	1.16 (0.73–1.85)
Quartile 4	3.71	45	1.12 (0.63–2.00)	2.50	50	1.25 (0.77–2.05)
P-trend[d]			0.74			0.32

	Ages 12–13 years			10 years before baseline		
	Median (frequency/day)	**Cases**	**HR (95% CI)[a]**	**Median (frequency/day)**	**Cases**	**HR (95% CI)[b]**
Chicken and turkey[h]						
Quartile 1	0–0.03	16	1.00 (reference)	0–0.13	55	1.00 (reference)
Quartile 2	0.04–0.13	39	0.93 (0.52–1.66)			
Quartile 3	0.14–0.41	96	1.29 (0.75–2.22)	0.14–0.41	87	0.87 (0.62–1.24)
Quartile 4	0.42	31	1.47 (0.78–2.76)	0.42	39	0.83 (0.54–1.29)
P-trend[d]			0.06			0.40
Red meat[i]						
Quartile 1	0.31	58	1.00 (reference)	0.16	62	1.00 (reference)
Quartile 2	0.72	45	1.02 (0.68–1.54)	0.43	47	0.86 (0.58–1.27)
Quartile 3	1.15	52	1.06 (0.69–1.61)	0.72	45	0.90 (0.59–1.38)
Quartile 4	1.78	27	0.68 (0.40–1.18)	1.21	27	0.72 (0.43–1.23)
P-trend[d]			0.34			0.30
Canned tuna[h]						
Quartile 1	0	50	1.00 (reference)	0–0.03	59	1.00 (reference)
Quartile 2	0.01–0.03	34	0.91 (0.59–1.41)			
Quartile 3	0.04–0.13	55	1.04 (0.70–1.54)	0.04–0.13	60	0.64 (0.45–0.92)
Quartile 4						
Quartile 3	1.00	50	0.77 (0.50–1.18)	1.00	52	1.47 (0.95–2.29)
Quartile 4	2.00	44	0.61 (0.38–0.98)	2.00	37	0.76 (0.47–1.25)
P-trend[d]			0.06			0.48
Sweet baked goods[j]						
Quartile 1	0.10	49	1.00 (reference)	0.05	41	1.00 (reference)
Quartile 2	0.43	35	0.82 (0.52–1.27)	0.20	50	1.76 (1.16–2.68)
Quartile 3	0.92	47	0.97 (0.63–1.50)	0.53	42	1.55 (0.98–2.45)
Quartile 4	1.64	51	1.62 (1.00–2.62)	1.21	48	1.87 (1.14–3.06)
P-trend[d]			0.07			0.02

CI – Confidence Interval; HR – Hazard Ratio

[a]Adjusted for total energy intake at ages 12–13 years, race/ethnicity, and education with age as the underlying time metric

[b] Adjusted for total energy intake 10 years before baseline, race/ethnicity, and education with age as the underlying time metric

[c] White bread or rolls and dark bread or rolls (rye, whole grain, whole wheat, pumpernickel)

[d] P-trend calculated by modeling the categorical variable as continuous

[e] Broccoli, carrots, lettuce salads, fresh tomatoes, tomato or vegetable soup, beans (such as baked beans, refried beans, pintos, kidney, or limas), and other vegetables (such as corn, peas, and green beans)

[f] Fresh, uncooked apples, orange or grapefruit juice, oranges, grapefruit, tangerines, and canned fruits (such as peaches, pears, and applesauce)

[g] Whole and low-fat milks, cheese and cheese spreads, pizza, and ice cream and milk shakes

[h] Due to clustering at specific intakes, categories were assigned

[i] Bacon, sausage, cold cuts/luncheon meats (such as ham, bologna, salami, corned beef, or pastrami), hotdogs/frankfurters, ground beef (in hamburgers, meatloaf, meatballs, or casseroles), roast beef, and steak

[j] Cookies, brownies, cake, donuts, sweet rolls, danish, sweet muffins, and dessert breads