The American Journal of Clinical Nutrition 119 (2024) 639–648

The American Journal of CLINICAL NUTRITION

journal homepage: https://ajcn.nutrition.org/

Original Research Article

Dietary patterns and their associations with sociodemographic and lifestyle factors in adult survivors of childhood cancer: a cross-sectional study

Tuo Lan [1], Mei Wang [1], Matthew J Ehrhardt [2,3], Jennifer Q Lanctot [2], Shu Jiang [1,4], Gregory T Armstrong [2,5], Kirsten K Ness [2,5], Melissa M Hudson [2,3,5], Graham A Colditz [1,4], Leslie L Robison [2,5], Yikyung Park [1,4,*]

[1] *Division of Public Health Sciences, Department of Surgery, Washington University School of Medicine, St. Louis, MO, United States;* [2] *Department of Epidemiology and Cancer Control, St. Jude Children's Research Hospital, Memphis, TN, United States;* [3] *Department of Oncology, St. Jude Children's Research Hospital, Memphis, TN, United States;* [4] *Alvin J. Siteman Cancer Center, Washington University School of Medicine, St. Louis, MO, United States;* [5] *Comprehensive Cancer Center, St. Jude Children's Research Hospital, Memphis, TN, United States*

A B S T R A C T

Background: Little is known about the specific dietary patterns in adult survivors of childhood cancer.

Objectives: We aimed to identify dietary patterns specific to childhood cancer survivors and examine their associations with sociodemographic and lifestyle factors.

Methods: Adult survivors of childhood cancer (mean:31 ± 8 y; $n = 3022$) and noncancer controls ($n = 497$) in the St. Jude Lifetime Cohort self-reported diet over the past 12 mo using a validated food frequency questionnaire. Factor analysis with 48 predefined food groups was performed to identify foods consumed together. Subsequently, cluster analysis with energy-adjusted factor scores was used to categorize survivors into a mutually exclusive dietary pattern. Dietary patterns were the primary outcomes. Multivariable multinomial logistic regressions were used to cross-sectionally examine associations between sociodemographic and lifestyle factors and dietary patterns in cancer survivors.

Results: Among the 4 dietary patterns identified, the fast-food pattern (36 %) was the most common, followed by the Western contemporary (30 %), the plant-based (20 %), and the animal-based (14 %) patterns in childhood cancer survivors. By contrast, the plant-based (38 %) and fast-food patterns (29 %) were prevalent in controls. In survivors, male sex, younger age, lower educational attainment, and physical inactivity were associated with the fast-food, Western contemporary, or animal-based pattern. Compared with non–Hispanic White survivors consuming the plant-based diet, non–Hispanic Black survivors were 2–5 times more likely to consume the fast-food [odds ratio (OR:= 2.76; 95 % CI: 1.82, 4.18) or the animal-based diet (OR: 5.61; 95 % CI: 3.58, 8.78)]. Moreover, survivors residing in the most deprived area were 2–3 times more likely to consume the fast-food, Western contemporary, or animal-based diet.

Conclusions: Unhealthy dietary patterns are prevalent in adult survivors of childhood cancer, especially those with lower socioeconomic status and racial minorities. Interventions to improve diet and health in childhood cancer survivors need to concurrently address disparities that contribute to adherence to healthy dietary practices.

This trial was registered at clinicaltrials.gov as NCT00760656 (https://classic.clinicaltrials.gov/ct2/show/NCT00760656).

Keywords: plant-based diet pattern, Western contemporary diet pattern, fast-food diet pattern, animal-based diet pattern, race/Hispanic origin, education

Introduction

With advances in cancer treatment and supportive care, childhood cancer survivors are a growing population that is expected to reach 6.7 million by 2030 worldwide [1]. However, it is now well-established that cancer survivors experience a high burden of chronic health conditions and excess risk for mortality than the general population [2,3]. Cancer and cancer treatment during childhood or adolescence can impact health behaviors. Hence, many childhood cancer survivors endorse health behaviors that differ from those of individuals with no cancer history [4–6]. For example, childhood cancer survivors are less likely to engage in physical activity comparable with the general population [7] and report lower smoking rates and alcohol consumption than the general population [4]. Nevertheless, previous studies

Abbreviations: OR, odds ratio; HEI, Healthy Eating Index; ADI, area deprivation index.

* Corresponding author.
E-mail address: yikyungpark@wustl.edu (Y. Park).

https://doi.org/10.1016/j.ajcnut.2024.01.012
Received 26 September 2023; Received in revised form 15 January 2024; Accepted 17 January 2024; Available online 24 January 2024

have suggested that adult survivors of childhood cancer may have suboptimal dietary practices and low adherence to dietary guidelines [5,8–11].

Diet is fundamental to prevent chronic diseases and maintain health in cancer survivors. Long-term survivors of childhood cancer are at a greater risk of developing numerous diet-related chronic diseases, such as obesity, diabetes, and heart diseases, at a younger age than the general population [12]. Nevertheless, little is known about eating habits of adult survivors of childhood cancers. A limited number of existing studies have mostly focused on intakes of specific foods, food groups, or nutrients and adherence to dietary recommendations [5,6,13]. To our knowledge, no study to date has comprehensively examined the totality of diet—dietary patterns—that describes foods and beverages habitually consumed in combinations and their frequencies and amounts in childhood cancer survivors. Moreover, it is not known what sociodemographic and lifestyle factors are associated with childhood cancer survivors' dietary patterns.

Advancing the understanding of dietary patterns and sociodemographic and lifestyle factors related to dietary patterns in childhood cancer survivors can identify vulnerable groups and potential targets for strategies to improve diet that may lead to better health and quality of life. Therefore, we aimed to characterize common dietary patterns in adult survivors of childhood cancer and examine sociodemographic and lifestyle factors that are associated with dietary patterns.

Methods

Study participants

St. Jude Lifetime Cohort was established to study the long-term health outcomes of childhood cancer survivors. Details of the cohort have been previously reported [14]. In brief, on September 2007, St. Jude Lifetime enrolled participants who were treated at St. Jude Children's Research Hospital in Memphis, TN, and had survived ≥5 y from a cancer diagnosis (response rate 69.9 %). Participation involves completion of self-administered health surveys assessing demographics, lifestyle, health behaviors (e.g., smoking and physical activity), and psychosocial outcomes and periodic comprehensive multisystem clinical evaluations (e.g., cardiac, reproductive, neuromuscular, neurocognitive, and psychosocial examinations). There were no significant differences in sociodemographic and cancer characteristics between participants and nonparticipants [15]. Age-matched, sex-matched, and race frequency–matched individuals with no history of childhood cancer (i.e., community controls) were also recruited from the same general geographic area as the survivors. All participants consented to the study, and the St. Jude Children's Research Hospital institutional review board reviewed and approved the study.

This study included both adult survivors (aged ≥18 y, $n = 4079$) and their community controls ($n = 737$) enrolled between 2007 and 2017. We excluded survivors who did not complete dietary assessments ($n = 234$); those who reported extremes of energy intake (<600 or >5000 kcal/d, $n = 232$); pregnant women ($n = 42$); individuals with inconsistent gender records ($n = 3$), chronic kidney disease ($n = 26$), or pancreatitis ($n = 17$); those who did not complete the health habits survey ($n = 31$); and those with missing information on dietary portion size ($n = 472$). We also excluded community controls with incomplete dietary assessment and missing demographics or lifestyle factors, such as smoking and physical activities ($n = 240$). Hence, the analytic sample included 3022 adult survivors of childhood cancer and 497 community controls (Supplemental Figure 1).

Dietary assessment

The 2005 Block Questionnaire, a 110-item food frequency questionnaire, previously validated with 24-h recalls, was administered to assess individual's diet, including dietary supplements use, over the past 12 mo [16]. Participants were asked to report their frequency of intake using 9 categories from never to every day and portion-size categories for each item. Pictures of foods were provided to assist in portion-size estimation. Nutrient intakes were estimated using the USDA Food and Nutrient Database for Dietary Studies.

We combined individual food items in the food frequency questionnaire into 48 food groups that have similar nutrient contents or culinary use (Supplemental Table 1). For example, broccoli, cabbage, coleslaw, and greens (e.g., collard, turnip, and mustard) were combined into "cruciferous vegetables." Foods that did not fit into any of the groups or that may have represented a particular dietary behavior (e.g., pizza, French fries, and wine) were left as a single food. Intake of a food group was calculated by summing the intake of individual items in the food group.

The Healthy Eating Index (HEI)-2015, which aligns with the 2015–2020 Dietary Guidelines for Americans, was calculated as a measure of overall diet quality [17]. It includes 9 adequacy components (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acid ratio) and 4 moderation components (refined grains, sodium, added sugars, and saturated fats). The HEI-2015 scores range from 0 to 100, and a higher score indicates a greater adherence to the dietary guidelines. A higher HEI score has been associated with a lower risk of chronic diseases, such as diabetes, cardiovascular disease, and cancer, and mortality [18,19].

Sociodemographics, lifestyle, and cancer history

Questionnaires were administered to collect information on demographics (e.g., age, sex, race/Hispanic origin, education, employment, income, and marital status), lifestyle and health behaviors (e.g., smoking, physical activity, and cancer impact on diet), self-assessed health status. Race/Hispanic origin was reported as non–Hispanic White, non–Hispanic Black, and Hispanic or other. All chronic health conditions (e.g., hypertension and diabetes) were assessed through questionnaires and were validated by a medical record review, and severity was graded by a modified version of the National Cancer Institute Common Terminology Criteria for Adverse Events, version 4.03 [20]. Neighborhood-level socioeconomic disadvantage was assessed using the area deprivation index (ADI), a measure that includes 17 socioeconomic status indicators, such as education, employment, housing quality, and poverty at the census block level [21]. ADI rankings were assigned on a scale of 1 to 100, representing national percentiles, where a higher percentile indicates a greater disadvantage. Cancer diagnosis and detailed treatment information (e.g., cumulative chemotherapy and region-specific radiotherapy doses) were obtained from medical records.

Statistical analysis

We used SAS version 9.4 for all statistical analyses. A 2-step approach was performed to identify dietary patterns. First, among survivors, factor analysis (PROC FACTOR procedure) was used (48 predefined food groups) to identify foods that were consumed together. The eigenvalue >1.0 criterion and Velicer minimum average partial test were used to determine the number of factors to retain. Three factors were identified and rotated by varimax rotation. A factor score

for each of the 3 identified factors was estimated by summing the factor loadings of each food group multiplied by the intake of the corresponding food group. For community controls, we also estimated factor scores using the linear combinations of the factor scoring coefficients obtained from survivors. All scores were energy-adjusted by the residual method [22]. Subsequently, we performed cluster analysis using the energy-adjusted factor scores to categorize participants into mutually exclusive dietary pattern groups. A *k* means clustering (PROC FASTCLUS procedure) was performed to identify aggregates of individuals. Plots of cubic clustering criterion, pseudo-F statistic, and pseudo T-square statistics from PROC CLUSTER were used to determine the number of clusters (Supplemental Figure 2). Four clusters were identified.

For comparisons of characteristics of survivors across dietary patterns, ANOVA for a continuous variable (age), and χ^2 test for categorical variables (all other variables) were performed. When data were missing in a categorical variable, a missing category was created. Multinomial logistic regression was used to estimate odds ratios (ORs) and 95 % CIs for the association between sociodemographic and lifestyle factors, health conditions, and dietary patterns in cancer survivors. Dietary patterns were the primary outcomes. Stepwise selection (SELECTION option) for all potential predictors with entry criteria of *P* value of 0.1 and exit criteria of *P* value of 0.05 were used. All selected predictors were included in a multivariable model.

Results

The 4 dietary patterns identified were as follows: *1*) plant-based, *2*) Western contemporary, *3*) fast-food, and *4*) animal-based patterns (Figure 1, Supplemental Figure 3, and Supplemental Tables 2 and 3). A plant-based pattern was characterized by greater intake of whole grains, fruit, vegetables, nuts and seeds, low-fat dairy, nonfried fish, and wine. On the contrary, a Western contemporary pattern was characterized by greater intake of pasta/rice, French fries, red meat, and salty snacks. A fast-food pattern had greater intake of high-fat dairy, processed meat, sweets and desserts, and sugar-sweetened beverages. An animal-based pattern had greater intake of all meats, such as poultry and fish, high-fat dairy, legumes, and beer/liquor.

Nutrient intakes and overall diet quality differed by the 4 dietary patterns (Table 1). The plant-based pattern had higher intakes of dietary fiber, vitamins, and minerals than other patterns. The Western contemporary pattern had the highest saturated fat intake but lowest vitamin C intake. The fast-food pattern had the highest intakes of carbohydrates and added and total sugars. The animal-based pattern had the highest protein and vitamin B12 intakes. Overall diet quality assessed by the HEI-2015 score was the highest in the plant-based pattern (mean = 72.6), and the lowest in the Western contemporary (mean = 56.2) and fast-food patterns (mean = 56.2). The animal-based pattern had the second-best HEI-2015 score (mean = 60.3).

In childhood cancer survivors, the fast-food pattern (36 %) was the most common dietary pattern, followed by the Western contemporary (30 %), plant-based (20 %), and the animal-based (14 %) patterns (Figure 2). In contrast to cancer survivors, the plant-based diet (38 %) was the most common dietary pattern in community controls, followed by the fast-food (29 %), Western contemporary (24 %), and animal-based (9 %) patterns. Among race/Hispanic origin groups, the most prevalent dietary pattern was the Western contemporary diet (33 %) in non–Hispanic White survivors, the fast-food diet (45 %) in non–Hispanic Black survivors, and the animal-based diet (35 %) in the other race/Hispanic origin survivor group.

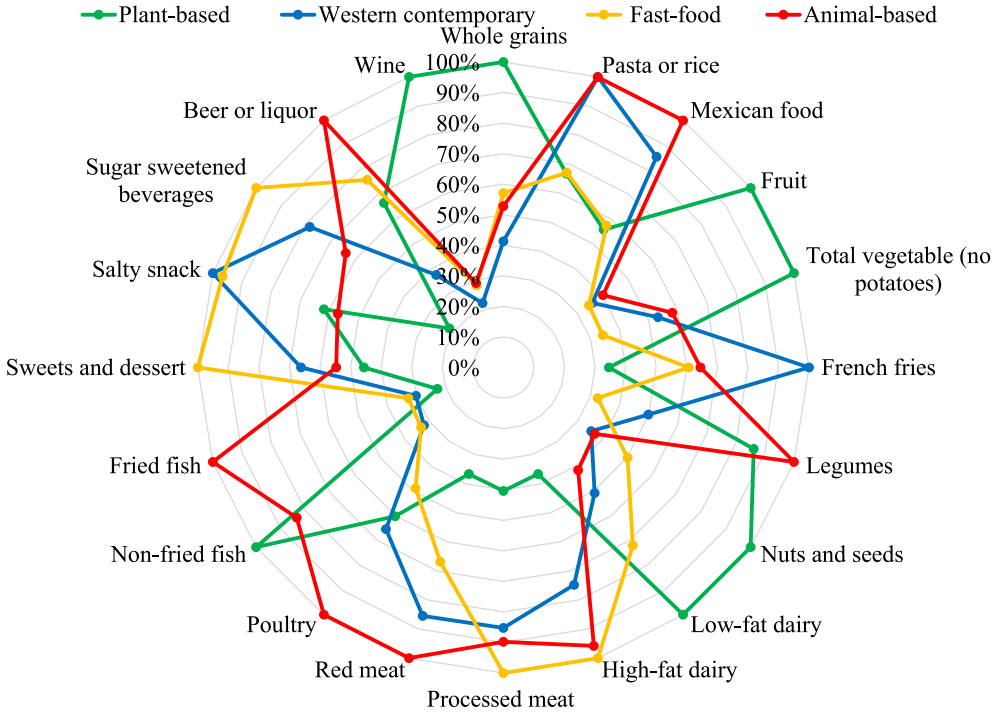

FIGURE 1. Radar plot of selected food intakes by identified dietary patterns in adult survivors of childhood cancer and community controls: St. Jude Lifetime Cohort Study. Food intakes are expressed as percentages of the highest mean intake for each food among 4 dietary patterns. For example, whole grain intake is the highest in the plant-based pattern (mean = 34.4 g/1000 kcal). Thus, whole grain intake in the Western contemporary pattern (mean = 14.2) is 41 % of the plant-based pattern. Total vegetable included all vegetable excluding potatoes, and sugar-sweetened beverages included soda, fruit drinks, and other sugar-sweetened beverages.

TABLE 1
Mean intakes of selected nutrients by dietary patterns in adult survivors of childhood cancer and community controls: St. Jude Lifetime Cohort Study[1]

	Dietary patterns			
	Plant-based	Western contemporary	Fast-food	Animal-based
n (%)	792 (22.5)	1021 (29.0)	1229 (34.9)	477 (13.5)
Carbohydrate (% of energy)	47.5 ± 8.4	47.7 ± 6.8	49.6 ± 8.1	44.3 ± 7.8
Protein (% of energy)	16.8 ± 3.0	14.9 ± 2.6	14.4 ± 2.9	17.7 ± 3.1
Total fat (% of energy)	36.2 ± 6.9	37.7 ± 5.2	35.8 ± 5.9	37.1 ± 5.4
Saturated fat	10.7 ± 2.6	12.1 ± 2.1	11.9 ± 2.3	11.8 ± 2.2
Monounsaturated fat	14.3 ± 3.2	14.6 ± 2.3	13.9 ± 2.5	14.5 ± 2.4
Polyunsaturated fat	8.5 ± 2.1	8.0 ± 1.8	7.1 ± 1.6	7.7 ± 1.5
Trans fats	1.0 ± 0.3	1.5 ± 0.5	1.3 ± 0.4	1.3 ± 0.4
Added sugars (g/1000 kcal)	24.7 ± 12.0	37.1 ± 19.6	44.7 ± 21.8	28.3 ± 15.2
Total sugars (g/1000 kcal)	56.3 ± 17.9	55.4 ± 20.0	67.1 ± 23.6	50.9 ± 20.0
Dietary fiber (g/1000 kcal)	12.3 ± 3.6	8.0 ± 2.2	6.9 ± 2.0	8.2 ± 2.6
Folate (μg/1000 kcal)	208.8 ± 73.5	117.1 ± 42.0	103.0 ± 31.2	137.6 ± 50.8
Vitamin B6 (mg/1000 kcal)	1.2 ± 0.3	0.9 ± 0.3	0.9 ± 0.3	1.0 ± 0.3
Vitamin B12 (μg/1000 kcal)	2.9 ± 1.1	2.4 ± 0.8	2.6 ± 1.0	3.3 ± 1.3
Vitamin C (mg/1000 kcal)	76.4 ± 32.8	40.3 ± 18.2	45.0 ± 24.9	58.4 ± 32.9
Vitamin E (mg/1000 kcal)	5.4 ± 1.6	3.7 ± 1.0	3.4 ± 1.0	3.8 ± 1.1
Calcium (mg/1000 kcal)	522.0 ± 160.6	399.0 ± 115.3	429.3 ± 145.6	408.0 ± 124.6
Potassium (mg/1000 kcal)	1728.1 ± 305.6	1215.7 ± 235.9	1159.4 ± 251.5	1314.5 ± 257.2
Magnesium (mg/1000 kcal)	200.6 ± 38.7	134.1 ± 26.8	132.4 ± 29.7	149.3 ± 36.7
Iron (mg/1000 kcal)	8.1 ± 1.8	6.7 ± 1.5	6.5 ± 1.6	7.3 ± 1.6
Healthy Eating Index-2015	72.6 ± 7.9	56.2 ± 8.8	56.2 ± 9.2	60.3 ± 8.6

[1] Variables were presented as means ± SDs.

Childhood cancer survivors in the study had a mean age of 31 y (SD = 8 y) (Table 2); 53 % were males, and 83 % were White, non–Hispanic adults. Of them, 60 % had cancer diagnosed at age ≤10 y, and the mean time since cancer diagnosis was 23 y. The most common childhood cancer diagnosis was leukemia (36 %), followed by lymphoma (19 %) and central nervous system tumors (12 %). Compared with the community controls, childhood cancer survivors were more likely to be male, present with lower educational attainment and income, live in more deprived areas (i.e., higher ADI), and be current smokers. The characteristics of childhood cancer survivors differed across dietary patterns. Survivors consuming a plant-based diet pattern were more likely to be older and female, have higher education attainment and income, full-time employment, live in less deprived areas, be nonsmokers, be physically active, use diet supplements, and have an excellent or very good health. By contrast, survivors endorsing the Western contemporary diet pattern tended to be non–Hispanic White and obese and self-rated their health as fair or poor, whereas survivors with the fast-food diet pattern were more likely to be male, be smokers, and have lower education. The animal-based diet consumers tended to be <30 y, male, and non-White. Similar characteristics were observed in the community controls. However, survivors who believed that their cancer experience had no impact on diet were more likely to follow the Western contemporary or fast-food diet.

Several sociodemographic factors, but not cancer history or treatment, were associated with dietary patterns in childhood cancer survivors (Table 3 and Supplemental Table 4). Compared with the plant-based diet, older age was associated with lower odds of consuming the Western contemporary (OR: 0.98; 95 % CI: 0.97, 0.99) and the animal-based diet (OR: 0.97; 95 % CI: 0.95, 0.99). On the contrary, survivors who were male, with lower education, and living in a more deprived area were associated with 2–5 times higher odds of consuming the Western contemporary, fast-food and animal-based diet. For example, survivors living in the most deprived area (ADI fourth quartile) were associated with 2–3 times higher odds of consuming the Western contemporary (OR: 3.05; 95 % CI: 2.11, 4.40), the fast-food (OR: 1.94; 95 % CI:1.35, 2.79), and the animal-based (OR: 2.23; 95 % CI: 1.45, 3.45) diet than those of survivors living in the least deprived area (ADI first quartile) and consuming the plant-based diet. Race/Hispanic origin was also associated with dietary patterns. Non–Hispanic Black survivors were associated with 2.8 and 5.6 times higher odds of consuming

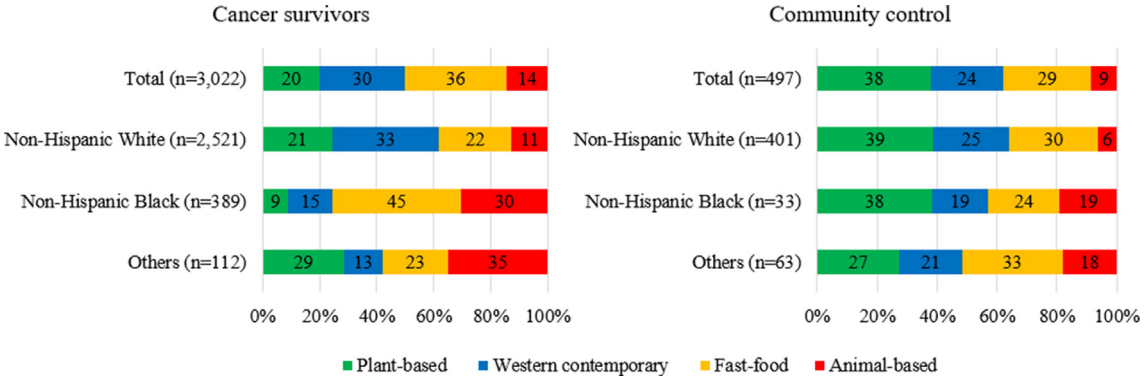

FIGURE 2. Prevalence of the dietary patterns in adult survivors of childhood cancer and community controls: St. Jude Lifetime Cohort Study.

TABLE 2
Participants' characteristics by dietary patterns in adult survivors of childhood cancer and community controls: St. Jude Lifetime Cohort Study[1]

	Survivors						Controls					
	Total	Plant-based	Western contemporary	Fast-food	Animal-based	P^2	Total	Plant-based	Western contemporary	Fast-food	Animal-based	P^2
No. of participants	3022	604	900	1084	434		497	188	121	145	43	
Age (y)	31.2 ± 8.4	32.2 ± 8.5	31.2 ± 8.4	31.2 ± 8.5	30 ± 8.0	<0.001	33.6 ± 10.2	36.2 ± 10.6	33.2 ± 9.7	31.6 ± 9.6	30.3 ± 9.9	<0.001
Age group (y)						0.008						0.048
<30	1498 (49.6)	268 (44.4)	452 (50.2)	533 (49.2)	245 (56.5)		196 (39.4)	61 (32.4)	44 (36.4)	67 (46.2)	24 (55.8)	
30 to <40	1032 (34.1)	224 (37.1)	310 (34.4)	363 (33.5)	135 (31.1)		165 (33.2)	66 (35.1)	44 (36.4)	44 (30.3)	11 (25.6)	
≥40	492 (16.3)	112 (18.5)	138 (15.3)	188 (17.3)	54 (12.4)		136 (27.4)	61 (32.4)	33 (27.3)	34 (23.4)	8 (18.6)	
Sex						<0.001						<0.001
Male	1590 (52.6)	187 (31.0)	442 (49.1)	667 (61.5)	294 (67.7)		215 (43.3)	59 (31.4)	52 (43.0)	76 (52.4)	28 (65.1)	
Female	1432 (47.4)	417 (69.0)	458 (50.9)	417 (38.5)	140 (32.3)		282 (56.7)	129 (68.6)	69 (57.0)	69 (47.6)	15 (34.9)	
Race/Hispanic origin						<0.001						0.009
Non–Hispanic White	2521 (83.4)	537 (88.9)	825 (91.7)	882 (81.4)	277 (63.8)		401 (80.7)	155 (82.4)	102 (84.3)	119 (82.1)	25 (58.1)	
Non–Hispanic Black	389 (12.9)	35 (5.8)	60 (6.7)	176 (16.2)	118 (27.2)		33 (6.6)	9 (4.8)	7 (5.8)	11 (7.6)	6 (14.0)	
Others	112 (3.7)	32 (5.3)	15 (1.7)	26 (2.4)	39 (9.0)		63 (12.7)	24 (12.8)	12 (9.9)	15 (10.3)	12 (27.9)	
Education[3]						<0.001						<0.001
Less than high school	261 (8.6)	19 (3.1)	82 (9.1)	117 (10.8)	43 (9.9)		9 (1.8)	2 (1.1)	2 (1.7)	3 (2.1)	2 (4.7)	
High school graduate	556 (18.4)	57 (9.4)	181 (20.1)	228 (21.0)	90 (20.7)		48 (9.7)	8 (4.3)	18 (14.9)	14 (9.7)	8 (18.6)	
Training after high school	994 (32.9)	159 (26.3)	307 (34.1)	381 (35.1)	147 (33.9)		135 (27.2)	35 (18.6)	41 (33.9)	51 (35.2)	8 (18.6)	
College or postgraduate	988 (32.7)	321 (53.1)	273 (30.3)	280 (25.8)	114 (26.3)		277 (55.7)	131 (69.7)	54 (44.6)	69 (47.6)	23 (53.5)	
Other	92 (3.0)	21 (3.5)	29 (3.2)	28 (2.6)	14 (3.2)		7 (1.4)	4 (2.1)	2 (1.7)	1 (0.7)	0 (0.0)	
Employment						<0.001						0.173
Full-time	1592 (52.7)	344 (57.0)	452 (50.2)	591 (54.5)	205 (47.2)		314 (63.2)	123 (65.4)	72 (59.5)	99 (68.3)	20 (46.5)	
Part-time	396 (13.1)	90 (14.9)	118 (13.1)	139 (12.8)	49 (11.3)		69 (13.9)	25 (13.3)	21 (17.4)	16 (11.0)	7 (16.3)	
Not working	452 (15.0)	67 (11.1)	128 (14.2)	167 (15.4)	90 (20.7)		38 (7.6)	10 (5.3)	9 (7.4)	14 (9.7)	5 (11.6)	
Unknown	582 (19.3)	103 (17.1)	202 (22.4)	187 (17.3)	90 (20.7)		76 (15.3)	30 (16.0)	19 (15.7)	16 (11.0)	11 (25.6)	
Income ($)						<0.001						<0.001
None	368 (12.2)	71 (11.8)	107 (11.9)	128 (11.8)	62 (14.3)		47 (9.5)	14 (7.4)	10 (8.3)	11 (7.6)	12 (27.9)	
≤19,999	1239 (41.0)	195 (32.3)	388 (43.1)	463 (42.7)	193 (44.5)		131 (26.4)	32 (17.0)	42 (34.7)	47 (32.4)	10 (23.3)	
20,000–39,999	683 (22.6)	145 (24.0)	201 (22.3)	250 (23.1)	87 (20.0)		115 (23.1)	44 (23.4)	28 (23.1)	34 (23.4)	9 (20.9)	
40,000–59,999	351 (11.6)	90 (14.9)	105 (11.7)	119 (11.0)	37 (8.5)		90 (18.1)	40 (21.3)	22 (18.2)	23 (15.9)	5 (11.6)	
≥60,000	291 (9.6)	93 (15.4)	68 (7.6)	92 (8.5)	38 (8.8)		106 (21.3)	55 (29.3)	18 (14.9)	26 (17.9)	7 (16.3)	
Area deprivation index[4]						<0.001						0.125
Quartile 1	606 (20.1)	195 (32.3)	141 (15.7)	193 (17.8)	77 (17.7)		186 (37.4)	78 (41.5)	39 (32.2)	56 (38.6)	13 (30.2)	
Quartile 2	674 (22.3)	142 (23.5)	212 (23.6)	243 (22.4)	77 (17.7)		119 (23.9)	47 (25.0)	32 (26.4)	31 (21.4)	9 (20.9)	
Quartile 3	703 (23.3)	114 (18.9)	227 (25.2)	275 (25.4)	87 (20.0)		107 (21.5)	40 (21.3)	19 (15.7)	37 (25.5)	11 (25.6)	
Quartile 4	724 (24.0)	76 (12.6)	248 (27.6)	265 (24.4)	135 (31.1)		80 (16.1)	21 (11.2)	29 (24.0)	21 (14.5)	9 (20.9)	
Unknown	315 (10.4)	77 (12.7)	72 (8.0)	108 (10.0)	58 (13.4)		5 (1.0)	2 (1.1)	2 (1.7)	0 (0.0)	1 (2.3)	
Marital status						<0.001						0.003
Not married	1580 (52.3)	292 (48.3)	444 (49.3)	571 (52.7)	273 (62.9)		183 (36.8)	60 (31.9)	35 (28.9)	63 (43.4)	25 (58.1)	
Married	1361 (45.0)	304 (50.3)	428 (47.6)	482 (44.5)	147 (33.9)		307 (61.8)	124 (66.0)	86 (71.1)	79 (54.5)	18 (41.9)	
Unknown	81 (2.7)	8 (1.3)	28 (3.1)	31 (2.9)	14 (3.2)		7 (1.4)	4 (2.1)	0 (0.0)	3 (2.1)	0 (0.0)	
Smoking						<0.001						0.459
Never	2058 (68.1)	456 (75.5)	609 (67.7)	702 (64.8)	291 (67.1)		356 (71.6)	138 (73.4)	84 (69.4)	103 (71.0)	31 (72.1)	
Former	228 (7.5)	34 (5.6)	66 (7.3)	96 (8.9)	32 (7.4)		39 (7.8)	15 (8.0)	9 (7.4)	10 (6.9)	5 (11.6)	
Current	498 (16.5)	57 (9.4)	160 (17.8)	206 (19.0)	75 (17.3)		47 (9.5)	10 (5.3)	15 (12.4)	18 (12.4)	4 (9.3)	
Unknown	238 (7.9)	57 (9.4)	65 (7.2)	80 (7.4)	36 (8.3)		55 (11.1)	25 (13.3)	13 (10.7)	14 (9.7)	3 (7.0)	
BMI (kg/m^2)						<0.001						0.078
<18.5	109 (3.6)	15 (2.5)	30 (3.3)	49 (4.5)	15 (3.5)		16 (3.2)	7 (3.7)	2 (1.7)	7 (4.8)	0 (0.0)	
18.5 to <25	1022 (33.8)	242 (40.1)	285 (31.7)	363 (33.5)	132 (30.4)		186 (37.4)	84 (44.7)	37 (30.6)	49 (33.8)	16 (37.2)	
25 to <30	862 (28.5)	174 (28.8)	237 (26.3)	292 (26.9)	159 (36.6)		140 (28.2)	48 (25.5)	32 (26.4)	46 (31.7)	14 (32.6)	
≥30	1029 (34.1)	173 (28.6)	348 (38.7)	380 (35.1)	128 (29.5)		155 (31.2)	49 (26.1)	50 (41.3)	43 (29.7)	13 (30.2)	

(*continued on next page*)

TABLE 2 (*continued*)

	Survivors						Controls					
	Total	Plant-based	Western contemporary	Fast-food	Animal-based	P^2	Total	Plant-based	Western contemporary	Fast-food	Animal-based	P^2
Physical activity[5]	2486 (82.3)	557 (92.2)	714 (79.3)	861 (79.4)	354 (81.6)	<0.001	446 (89.7)	182 (96.8)	103 (85.1)	122 (84.1)	39 (90.7)	<0.001
Multivitamin use	800 (26.5)	246 (40.7)	208 (23.1)	255 (23.5)	91 (21.0)	<0.001	146 (29.4)	68 (36.2)	29 (24.0)	35 (24.1)	14 (32.6)	0.046
Single supplement use	1160 (38.4)	334 (55.3)	304 (33.8)	373 (34.4)	149 (34.3)	<0.001	217 (43.7)	99 (52.7)	47 (38.8)	53 (36.6)	18 (41.9)	0.016
Healthy Eating Index-2015	60.1 ± 11.0	73.2 ± 7.7	56.1 ± 8.9	56.2 ± 9.2	60.1 ± 8.8	<0.001	62.4 ± 10.9	70.8 ± 8.4	56.7 ± 8.2	56.0 ± 9.3	62.3 ± 6.6	<0.001
Health status[3]						<0.001						0.005
Excellent or very good	1300 (43.0)	347 (57.5)	339 (37.7)	419 (38.7)	195 (44.9)		308 (62.0)	137 (72.9)	60 (49.6)	81 (55.9)	30 (69.8)	
Good	628 (20.8)	77 (12.7)	203 (22.6)	261 (24.1)	87 (20.0)		47 (9.5)	13 (6.9)	15 (12.4)	15 (10.3)	4 (9.3)	
Fair or poor	1052 (34.8)	176 (29.1)	346 (38.4)	386 (35.6)	144 (33.2)		139 (28.0)	36 (19.1)	45 (37.2)	49 (33.8)	9 (20.9)	
Hypertension[6]	296 (9.8)	43 (7.1)	118 (13.1)	100 (9.2)	35 (8.1)	<0.001						
High cholesterol[6]	183 (6.1)	38 (6.3)	54 (6.0)	66 (6.1)	25 (5.8)	0.988						
Cardiovascular disease[6]	468 (15.5)	69 (11.4)	154 (17.1)	175 (16.1)	70 (16.1)	0.019						
Diabetes[6]	99 (3.3)	24 (4.0)	27 (3.0)	36 (3.3)	12 (2.8)	0.680						
Age at cancer diagnosis (y)						0.068						
<10	1808 (59.8)	329 (54.5)	548 (60.9)	655 (60.4)	276 (63.6)							
10 to <15	696 (23.0)	150 (24.8)	203 (22.6)	249 (23.0)	94 (21.7)							
≥15	518 (17.1)	125 (20.7)	149 (16.6)	180 (16.6)	64 (14.7)							
Cancer diagnosis												
Central nervous system	358 (11.8)	57 (9.4)	103 (11.4)	134 (12.4)	64 (14.7)	0.064						
Leukemia	1098 (36.3)	214 (35.4)	347 (38.6)	375 (34.6)	162 (37.3)	0.291						
Lymphoma	570 (18.9)	146 (24.2)	154 (17.1)	201 (18.5)	69 (15.9)	0.001						
Other	996 (33.0)	187 (31.0)	296 (32.9)	374 (34.5)	139 (32.0)	0.488						
Cancer treatment												
Chest radiation	713 (23.6)	158 (26.2)	210 (23.3)	240 (22.1)	105 (24.2)	0.309						
Cranial radiation	998 (33.0)	205 (33.9)	298 (33.1)	357 (32.9)	138 (31.8)	0.912						
Abdomen radiation	651 (21.5)	127 (21.0)	196 (21.8)	225 (20.8)	103 (23.7)	0.625						
Anthracycline chemotherapy	1749 (57.9)	334 (55.3)	547 (60.8)	610 (56.3)	258 (59.4)	0.096						
Alkylating agent chemotherapy	1874 (62.0)	362 (59.9)	564 (62.7)	675 (62.3)	273 (62.9)	0.694						
Platinum-based chemotherapy	388 (12.8)	68 (11.3)	112 (12.4)	143 (13.2)	65 (15.0)	0.338						
Cancer impact diet[7]						<0.001						
Positive impact	607 (20.1)	214 (35.4)	138 (15.3)	161 (14.9)	94 (21.7)							
No impact	1918 (63.5)	310 (51.3)	614 (68.2)	737 (68.0)	257 (59.2)							
Negative impact	497 (16.4)	80 (13.2)	148 (16.4)	186 (17.2)	83 (19.1)							

[1] Continuous variables are presented as means ± SDs, and categorical variables are shown as n (%).

[2] χ^2 test was used to compare categorical variables and ANOVA to compare continuous variables.

[3] Numbers may not add ≤100 % owing to missing data.

[4] Higher the index, the more deprived areas.

[5] Participants who answered to "no" to "I rarely or never do any physical activities."

[6] All chronic health conditions were collected by administered questionnaires and validated by medical record review, and severity was graded by a modified version of the National Cancer Institute Common Terminology Criteria for Adverse Events, version 4.03.

[7] Participants were asked about "Looking back over time since your cancer diagnosis, how much of an impact did your cancer experiences have on your diet overall?"

TABLE 3
Multivariable-adjusted odds ratios and 95 % CIs of sociodemographic and lifestyle factors for dietary patterns in adult survivors of childhood cancer: St. Jude Lifetime Cohort Study

	Compared with plant-based diet pattern		
	Western contemporary	Fast-food	Animal-based
Age (y)	0.98 (0.97, 0.99)	0.98 (0.97, 1.00)	0.97 (0.95, 0.99)
Sex			
Female	1.00	1.00	1.00
Male	2.24 (1.77, 2.84)	3.90 (3.09, 4.93)	5.82 (4.35, 7.80)
Race/Hispanic origin			
Non–Hispanic White	1.00	1.00	1.00
Non–Hispanic Black	0.83 (0.52, 1.32)	2.76 (1.82, 4.18)	5.61 (3.58, 8.78)
Others	0.41 (0.21, 0.81)	0.64 (0.35, 1.15)	2.71 (1.54, 4.77)
Education			
Less than high school	2.35 (1.33, 4.15)	3.75 (2.15, 6.54)	2.88 (1.52, 5.48)
High school graduate	2.05 (1.41, 2.97)	2.66 (1.84, 3.85)	2.29 (1.47, 3.57)
Training after high school	1.64 (1.25, 2.17)	2.03 (1.55, 2.67)	1.71 (1.20, 2.42)
College or postgraduate	1.00	1.00	1.00
Other	1.38 (0.73, 2.62)	1.43 (0.75, 2.72)	1.32 (0.61, 2.88)
Employment			
Full-time	1.00	1.00	1.00
Part-time	0.90 (0.64, 1.28)	0.83 (0.59, 1.17)	0.83 (0.54, 1.29)
Not working	0.94 (0.65, 1.36)	0.86 (0.60, 1.24)	1.46 (0.96, 2.22)
Unknown	1.20 (0.88, 1.65)	0.81 (0.59, 1.12)	1.23 (0.84, 1.81)
Area deprivation index[1]			
Quartile 1	1.00	1.00	1.00
Quartile 2	1.70 (1.23, 2.35)	1.37 (1.00, 1.88)	1.16 (0.77, 1.75)
Quartile 3	1.95 (1.39, 2.73)	1.59 (1.15, 2.21)	1.29 (0.85, 1.97)
Quartile 4	3.05 (2.11, 4.40)	1.94 (1.35, 2.79)	2.23 (1.45, 3.45)
Unknown	1.15 (0.75, 1.74)	1.15 (0.77, 1.71)	1.37 (0.85, 2.21)
BMI (kg/m^2)			
<18.5	1.57 (0.78, 3.14)	2.01 (1.03, 3.93)	1.73 (0.76, 3.94)
18.5 to <25	1.00	1.00	1.00
25 to <30	0.89 (0.67, 1.18)	0.77 (0.58, 1.02)	1.22 (0.87, 1.71)
30+	1.07 (0.81, 1.43)	0.86 (0.65, 1.15)	0.92 (0.64, 1.32)
Physical activity			
Yes	1.00	1.00	1.00
No	2.48 (1.72, 3.57)	2.34 (1.63, 3.37)	1.93 (1.26, 2.95)
Single supplement use			
Yes	1.00	1.00	1.00
No	1.74 (1.39, 2.19)	1.57 (1.25, 1.97)	1.57 (1.18, 2.08)
Health status			
Excellent or very good	1.00	1.00	1.00
Good	1.51 (1.16, 1.97)	1.46 (1.12, 1.89)	1.34 (0.98, 1.85)
Fair or poor	1.49 (1.04, 2.12)	1.65 (1.16, 2.33)	1.18 (0.77, 1.81)
Cancer impact diet[2]			
Positive impact	1.00	1.00	1.00
No impact	2.35 (1.79, 3.09)	2.50 (1.91, 3.28)	1.67 (1.20, 2.32)
Negative impact	1.75 (1.20, 2.57)	2.03 (1.40, 2.95)	1.80 (1.15, 2.81)

[1] Higher the index, the more deprived areas.
[2] Participants were asked about "Looking back over time since your cancer diagnosis, how much of an impact did your cancer experiences have on your diet overall?"

the fast-food diet (OR: 2.76; 95 % CI: 1.82, 4.18) and the animal-based pattern (OR: 5.61; 95 % CI: 3.58, 8.78), respectively, whereas survivors of other race/Hispanic origin were associated with 2.7 times higher odds of consuming the animal-based diet (OR: 2.71; 95 % CI: 1.54, 4.77) than non–Hispanic White survivors consuming the plant-based diet.

In addition, health behaviors such as physical activity and dietary supplement use, self-rated health status, and perceived impact of cancer on diet were related to dietary patterns. Physical inactivity was associated with higher odds of consuming the Western contemporary (OR: 2.48; 95 % CI: 1.72, 3.57), the fast-food diet (OR: 2.34; 95 % CI: 1.63, 3.37), and the animal-based (OR: 1.93; 95 % CI: 1.26, 2.95) than that of the plant-based diet. Not using single supplements and self-rated suboptimal health were associated with approximately 1.5–1.7 times higher odds of consuming the Western contemporary, fast-food, or animal-based diet than the plant-based diet. Survivors who responded that their cancer experience had no impact on diet after cancer diagnosis showed 1.7–2.5 times higher odds of consuming the Western contemporary (OR: 2.35; 95 % CI: 1.79, 3.09), the fast-food (OR: 1.67; 95 % CI: 1.20, 2.32), or the animal-based diet (OR: 2.50; 95 % CI: 1.91, 3.28) than those who reported a positive impact on their diet after cancer diagnosis and consumed the plant-based diet.

Discussion

In this study of adult survivors of childhood cancer and age-matched, sex-matched, and race-matched people with no history of cancer, we found that the majority of survivors consumed a fast-food, Western contemporary, or animal-based diet, a nutritionally suboptimal diet with greater intake of meat, refined grains, salty snacks, sweets, and desserts, and smaller amounts of fruits, vegetables, and whole grains. Survivors' sociodemographics—age, sex, race/Hispanic origin, education, and residential area—and health behaviors, such as physical activity and perceived cancer impact on diet, were associated with dietary patterns. Conversely, specific cancer types and their treatments were not associated with dietary patterns after adjustment for sociodemographic and lifestyle factors.

Similar to previous studies that reported low adherence to dietary guidelines in adult survivors of childhood cancer guidelines [5,8–11], we found that unhealthy diets—fast-food or the Western contemporary pattern—were prevalent, and only 1 of the 5 survivors endorsed intake of a healthy plant-based diet. The prevalence of a plant-based diet in cancer survivors (20 %) was lower than that in community controls (38 %). However, the community controls' overall diet quality as assessed by the HEI score was significantly higher (mean = 62.4) than that of those aged 19–59 y in the National Health and Nutrition Examination Survey (mean HEI = 55.3) [23], suggesting that controls may not be completely representative of the population in United States. Community controls also reported higher educational attainment and incomes and lived in less deprived areas than childhood cancer survivors.

However, we identified an animal-based diet pattern that was high in all meats—red meat, poultry, and fish—and moderate consumption of fruit and vegetables. The animal-based diet's overall diet quality was better than that of the fast-food and Western contemporary diet but poorer than the quality of the plant-based diet. Moreover, high consumption of meat and protein from animal foods has been associated with an increased risk of overall and cardiovascular mortality in the general population, suggesting the animal-based pattern is another type of unhealthy diet [24–26].

The most prevalent dietary pattern differed by cancer survivors' race/Hispanic origin. In non–Hispanic White survivors, the Western contemporary diet was the most frequently consumed, followed by the fast-food diet. On the contrary, the fast-food diet, followed by the animal-based diet were most prevalent in non–Hispanic Black survivors, and the animal-based and the plant-based diet were most prevalent in other racial/Hispanic origin groups. On a national level, meat consumption is the highest in non–Hispanic Black adults, followed by other race/Hispanic origin groups, Hispanics, and non–Hispanic White adults [27]. These national data are supported by data from a cohort of community-dwelling Black and White adults, where persons who endorse Black race were more likely than those endorsing White race to consume a diet high in red, processed, and organ meat, shellfish, fried food, refined grains, and sugar-sweeten beverages, similar to the animal-based or fast-food diet pattern that we identified [28]. These race/Hispanic origin differences are likely partly because of cultural, social and community preferences, perceptions, and knowledge about a healthy diet [29–32]. Thus, dietary counseling, education, and interventions need to include cultural factors that affect food choices and preferences.

Consistent with other studies conducted in the general population [33,34], we found that other sociodemographic factors were associated with dietary patterns in childhood cancer survivors. Older age, female sex, and higher education level were associated with a plant-based diet, whereas lower education levels and living in a disadvantaged neighborhood were associated with fast-food, Western contemporary, or animal-based diet [34–37]. Fewer healthy food choices and less access to fresh fruits and vegetables, but a higher proportion of fast-food restaurants in disadvantaged neighborhoods [33,38] may lead those residents to have a greater consumption of fast-food and animal-based diet. It is also noteworthy that education, rather than income, was associated with a healthier diet in cancer survivors, as shown in another study that education, but not income, influenced health-conscious dietary behaviors [34]. Furthermore, higher education level was related to favorable health behavior change after cancer diagnosis in survivors of adult cancer [39] because we also noted that childhood cancer survivors who believed their cancer experience had no or negative impact on diet after cancer were more likely to have a suboptimal diet. These findings are in line with barriers and facilitators to health behavior adoption and maintenance previously reported in childhood cancer survivors, which include knowledge, beliefs about consequences, environmental context and resources, and social influences [40]. Therefore, efforts directed toward not only enhancing access to healthful food choices within disadvantaged neighborhoods but also providing nutrition education to individuals and communities are important.

Cancer type and treatment have been postulated to affect survivors' eating habits due to changes in taste, appetite, and satiety. For example, increased intracranial pressure and infiltration associated with brain tumors may impair satiety signaling through hypothalamic–pituitary axis injury [41,42]. Radiation to head/neck and abdomen fields may disrupt hypothalamic–pituitary function and gut hormone secretion, respectively, resulting in taste and smell alterations in food preferences [43–45]. However, in our study, cancer treatment was not associated with dietary patterns. Moreover, unlike the studies of the general population that found positive associations of smoking and obesity with an unhealthy diet [36,37], our study of adult survivors of childhood cancer found no relationships between them. This may be because smoking habits and obesity in childhood cancer survivors are also affected by cancer and cancer treatment [43,46,47].

This study has several limitations. Although our study included a large geographically diverse group of childhood cancer survivors, they were predominantly non–Hispanic White adults, limiting our ability to examine diet disparity in other race/Hispanic origin groups. Moreover, it is possible that survivors with implausible or missing diet data may have unhealthier diet patterns. Excluding these survivors may underestimate the prevalence of unhealthier diet patterns. Some survivors' dietary patterns may have also been incorrectly identified owing to inherent limitations in self-reported diet, such as miss-reporting (e.g., forgetting or omitting foods and beverages, especially foods perceived as unhealthy) and inaccurate portion-size estimation. To reduce these measurement errors, we excluded survivors with extreme energy intake and adjusted for energy in analyses. A further limitation is that the dietary patterns were identified using factor and cluster analysis, which relies on the observed data, as opposed to a score-based analysis assessing the adherence to a recommended diet (e.g., HEI and Mediterranean diet). This data-driven approach presents difficulties in consistently reproducing the identified patterns across various studies. However, this method provided an opportunity to identify dietary patterns unique to childhood cancer survivors.

The study also has strengths. Dietary patterns were identified in a large number of adult survivors of childhood cancer with various cancer types and treatment histories in a wide age range. Moreover, the study had comprehensive data on diet, sociodemographic factors, including ADI, a neighborhood-level socioeconomic disadvantage

index, lifestyle, and cancer history and treatment. Moreover, we used a 2-step approach to identify dietary patterns—first grouped foods that tended to be consumed together and then classified survivors who had similar diet patterns, thus creating mutually exclusive dietary patterns that make the interpretation of comparison among dietary patterns clear.

In conclusion, the overwhelming majority of adult survivors of childhood cancer had unhealthy dietary patterns that are high in animal-based foods, salty snacks, desserts, and sugar-sweetened beverages. Moreover, sociodemographic factors that were associated with unhealthy dietary patterns in childhood cancer survivors are also known contributors to health disparities. Health interventions aiming to improve diet quality will have to concurrently address disparities that contribute to adherence to healthy dietary practices in childhood cancer survivors.

Authors' contributions

The authors' responsibilities were as follows – YP, MMH, LLR: conceptualized the study; MW, JQL: curated the data; MMH, GAC, LLR, YP: was responsible for funding acquisition; TL, MW, SJ: performed the formal analysis; TL, MW, MJE, SJ, JQL, GTA, KKN, MMH, GAC, LLR, YP: performed the investigation; GTA, MMH, LLR, YP: administered the project. MMH, GAC, LLR, YP: supervised the study. TL, YP: wrote the original draft. MW, MJE, SJ, JQL, GTA, KKN, MMH, GAC, LLR: reviewed and edited the manuscript; and all authors: have read and approved the final version.

Conflict of interest

The authors report no conflicts of interest.

Funding

The study was supported in part by the National Institutes of Health Grants R03CA252485, U01CA195547 (M.M.H./K.K.N. principal investigators), P30CA091842, and Cancer Center Support Grant CA21765 (C.R., principal investigator). The study was also supported by the St. Jude Children's Research Hospital-Washington University St. Louis Implementation Sciences Collaborative and the American Lebanese-Syrian Associated Charities (ALSAC).

Data availability

Data can be obtained on request. Requests should be directed to the St. Jude LIFE (https://sjlife.stjude.org/), which has a protocol for approving data requests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2024.01.012.

References

[1] Z.J. Ward, J.M. Yeh, N. Bhakta, A.L. Frazier, R. Atun, Estimating the total incidence of global childhood cancer: a simulation-based analysis, Lancet Oncol 20 (4) (2019) 483–493, https://doi.org/10.1016/s1470-2045(18)30909-4.

[2] NCI, Cancer in Children and Adolescents [Internet], 2021. Available from: https://www.cancer.gov/types/childhood-cancers/child-adolescent-cancers-fact-sheet. (Accessed 18 October 2022).

[3] M.J. Ehrhardt, K.R. Krull, N. Bhakta, Q. Liu, Y. Yasui, L.L. Robison, M.M. Hudson, Improving quality and quantity of life for childhood cancer survivors globally in the twenty-first century, Nat. Rev. Clin. Oncol. 20 (10) (2023) 1–19.

[4] S.A. Clarke, C. Eiser, Health behaviours in childhood cancer survivors: a systematic review, Eur. J. Cancer. 43 (9) (2007) 1373–1384, https://doi.org/10.1016/j.ejca.2007.03.002.

[5] M.R. Stolley, J. Restrepo, L.K. Sharp, Diet and physical activity in childhood cancer survivors: a review of the literature, Ann. Behav. Med. 39 (3) (2010) 232–249, https://doi.org/10.1007/s12160-010-9192-6.

[6] C.A. Berdan, C.C. Tangney, C. Scala, M. Stolley, Childhood cancer survivors and adherence to the American Cancer Society Guidelines on Nutrition and Physical Activity, J. Cancer Surviv. 8 (4) (2014) 671–679, https://doi.org/10.1007/s11764-014-0376-0.

[7] K.K. Ness, W.M. Leisenring, S. Huang, M.M. Hudson, J.G. Gurney, K. Whelan, et al., Predictors of inactive lifestyle among adult survivors of childhood cancer: a report from the Childhood Cancer Survivor Study, Cancer 115 (9) (2009) 1984–1994, https://doi.org/10.1002/cncr.24209.

[8] F.F. Zhang, S. Liu, E.M. John, A. Must, W. Demark-Wahnefried, Diet quality of cancer survivors and noncancer individuals: results from a national survey, Cancer 121 (23) (2015) 4212–4221, https://doi.org/10.1002/cncr.29488.

[9] F.F. Zhang, E. Saltzman, M.J. Kelly, S. Liu, A. Must, S.K. Parsons, et al., Comparison of childhood cancer survivors' nutritional intake with US dietary guidelines, Pediatr. Blood Cancer. 62 (8) (2015) 1461–1467, https://doi.org/10.1002/pbc.25521.

[10] F.N. Belle, A. Chatelan, R. Kasteler, L. Mader, I. Guessous, M. Beck-Popovic, et al., Dietary intake and diet quality of adult survivors of childhood cancer and the general population: results from the SCCSS-Nutrition study, Nutrients 13 (6) (2021) 1767, https://doi.org/10.3390/nu13061767.

[11] K. Robien, K.K. Ness, L.M. Klesges, K.S. Baker, J.G. Gurney, Poor adherence to dietary guidelines among adult survivors of childhood acute lymphoblastic leukemia, J. Pediatr. Hematol. Oncol. 30 (11) (2008) 815–822, https://doi.org/10.1097/MPH.0b013e31817e4ad9.

[12] N. Bhakta, Q. Liu, K.K. Ness, M. Baassiri, H. Eissa, F. Yeo, et al., The cumulative burden of surviving childhood cancer: an initial report from the St Jude Lifetime Cohort Study (SJLIFE), Lancet 390 (10112) (2017) 2569–2582, https://doi.org/10.1016/s0140-6736(17)31610-0.

[13] A.J. Murphy-Alford, M. White, L. Lockwood, A. Hallahan, P.S.W. Davies, Body composition, dietary intake and physical activity of young survivors of childhood cancer, Clin. Nutr. 38 (2) (2019) 842–847, https://doi.org/10.1016/j.clnu.2018.02.020.

[14] C.R. Howell, K.L. Bjornard, K.K. Ness, N. Alberts, G.T. Armstrong, N. Bhakta, T. Brinkman, et al., Cohort profile: the St. Jude Lifetime Cohort Study (SJLIFE) for paediatric cancer survivors, Int. J. Epidemiol. 50 (1) (2021) 39–49, https://doi.org/10.1093/ije/dyaa203.

[15] R.P. Ojha, S.C. Oancea, K.K. Ness, J.Q. Lanctot, D.K. Srivastava, L.L. Robison, et al., Assessment of potential bias from non-participation in a dynamic clinical cohort of long-term childhood cancer survivors: results from the St. Jude Lifetime Cohort Study, Pediatr. Blood Cancer. 60 (5) (2013) 856–864, https://doi.org/10.1002/pbc.24348.

[16] G. Block, M. Woods, A. Potosky, C. Clifford, Validation of a self-administered diet history questionnaire using multiple diet records, J. Clin. Epidemiol. 43 (12) (1990) 1327–1335, https://doi.org/10.1016/0895-4356(90)90099-b.

[17] HHS. U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015–2020 Dietary Guidelines for Americans [Internet], 8th Edition, December 2015. Available from: https://health.gov/our-work/food-nutrition/previous-dietary-guidelines/2015. (Accessed 13 September 2022).

[18] M.L. McCullough, D. Feskanich, M.J. Stampfer, E.L. Giovannucci, E.B. Rimm, F.B. Hu, et al., Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance, Am. J. Clin. Nutr. 76 (6) (2002) 1261–1271, https://doi.org/10.1093/ajcn/76.6.1261.

[19] J. Reedy, J.L. Lerman, S.M. Krebs-Smith, S.I. Kirkpatrick, T.E. Pannucci, M.M. Wilson, et al., Evaluation of the Healthy Eating Index-2015, J. Acad. Nutr. Diet. 118 (9) (2018) 1622–1633, https://doi.org/10.1016/j.jand.2018.05.019.

[20] M.M. Hudson, M.J. Ehrhardt, N. Bhakta, M. Baassiri, H. Eissa, W. Chemaitilly, et al., Approach for classification and severity grading of long-term and late-onset health events among childhood cancer survivors in the St. Jude Lifetime Cohort, Cancer Epidemiol. Biomarkers Prev. 26 (5) (2017) 666–674, https://doi.org/10.1158/1055-9965.Epi-16-0812.

[21] M.J. Ehrhardt, Q. Liu, S.B. Dixon, E. Caron, D. Redd, K. Shelton, et al., Association of modifiable health conditions and social determinants of health with late mortality in survivors of childhood cancer, JAMA Netw. Open. 6 (2) (2023) e2255395.

[22] W.C. Willett, G.R. Howe, L.H. Kushi, Adjustment for total energy intake in epidemiologic studies, Am. J. Clin. Nutr. 65 (4 Suppl) (1997) 1220S–1228S, https://doi.org/10.1093/ajcn/65.4.1220S, discussion 9S–31S.

[23] M.M. Shams-White, T.E. Pannucci, J.L. Lerman, K.A. Herrick, M. Zimmer, K. Meyers, Mathieu, et al., Healthy Eating Index-2020: review and update process to reflect the dietary guidelines for Americans,2020-2025, J. Acad.

Nutr. Diet. 123 (9) (2023) 1280–1288, https://doi.org/10.1016/j.jand.2023.05.015.
[24] Z. Chen, M. Glisic, M. Song, H.A. Aliahmad, X. Zhang, A.C. Moumdjian, et al., Dietary protein intake and all-cause and cause-specific mortality: results from the Rotterdam Study and a meta-analysis of prospective cohort studies, Eur. J. Epidemiol. 35 (5) (2020) 411–429, https://doi.org/10.1007/s10654-020-00607-6.
[25] M. Song, T.T. Fung, F.B. Hu, W.C. Willett, V.D. Longo, A.T. Chan, et al., Association of animal and plant protein intake with all-cause and cause-specific mortality, JAMA Intern. Med. 176 (10) (2016) 1453–1463, https://doi.org/10.1001/jamainternmed.2016.4182.
[26] V.W. Zhong, L. Van Horn, P. Greenland, M.R. Carnethon, H. Ning, J.T. Wilkins, et al., Associations of processed meat, unprocessed red meat, poultry, or fish intake with incident cardiovascular disease and all-cause mortality, JAMA Intern. Med. 180 (4) (2020) 503–512, https://doi.org/10.1001/jamainternmed.2019.6969.
[27] L. Zeng, M. Ruan, J. Liu, P. Wilde, E.N. Naumova, D. Mozaffarian, et al., Trends in processed meat, unprocessed red meat, poultry, and fish consumption in the United States, 1999-2016, J. Acad. Nutr. Diet. 119 (7) (2019) 1085–1098, https://doi.org/10.1016/j.jand.2019.04.004, e12.
[28] J.M. Shikany, M.M. Safford, P.K. Newby, R.W. Durant, T.M. Brown, S.E. Judd, Southern dietary pattern is associated with hazard of acute coronary heart disease in the reasons for geographic and racial differences in stroke (REGARDS) study, Circulation 132 (9) (2015) 804–814, https://doi.org/10.1161/circulationaha.114.014421.
[29] S.C. Lucan, F.K. Barg, A. Karasz, C.S. Palmer, J.A. Long, Concepts of healthy diet among urban, low-income, African Americans, J. Community Health. 37 (4) (2012) 754–762, https://doi.org/10.1007/s10900-011-9508-x.
[30] J.A. Satia, Diet-related disparities: understanding the problem and accelerating solutions, J. Am. Diet. Assoc. 109 (4) (2009) 610–615, https://doi.org/10.1016/j.jada.2008.12.019.
[31] J.L. Watters, J.A. Satia, J.A. Galanko, Associations of psychosocial factors with fruit and vegetable intake among African-Americans, Public Health Nutr 10 (7) (2007) 701–711, https://doi.org/10.1017/s1368980007662284.
[32] A.S. Ojo, L.A. Nnyanzi, E.L. Giles, L.J. Ells, O. Awolaran, S.R. Okeke, et al., Perceptions of dietary intake amongst Black, Asian and other minority ethnic groups in high-income countries: a systematic review of qualitative literature, BMC Nutr 9 (1) (2023) 85, https://doi.org/10.1186/s40795-023-00743-8.
[33] N.I. Larson, M.T. Story, M.C. Nelson, Neighborhood environments: disparities in access to healthy foods in the U.S, Am. J. Prev. Med. 36 (1) (2009) 74–81, https://doi.org/10.1016/j.amepre.2008.09.025.
[34] U. Klink, J. Mata, R. Frank, B. Schüz, Socioeconomic differences in animal food consumption: education rather than income makes a difference, Front. Nutr. 9 (2022) 993379, https://doi.org/10.3389/fnut.2022.993379.
[35] E. Kesse-Guyot, S. Bertrais, S. Péneau, C. Estaquio, L. Dauchet, A.C. Vergnaud, et al., Dietary patterns and their sociodemographic and behavioural correlates in French middle-aged adults from the SU.VI.MAX cohort, Eur. J. Clin. Nutr. 63 (4) (2009) 521–528, https://doi.org/10.1038/sj.ejcn.1602978.
[36] K. Roberts, J. Cade, J. Dawson, M. Holdsworth, Empirically derived dietary patterns in UK adults are associated with sociodemographic characteristics, lifestyle, and diet quality, Nutrients 10 (2) (2018) 177, https://doi.org/10.3390/nu10020177.
[37] M. Touvier, M. Niravong, J.L. Volatier, L. Lafay, S. Lioret, F. Clavel-Chapelon, et al., Dietary patterns associated with vitamin/mineral supplement use and smoking among women of the E3N-EPIC cohort, Eur. J. Clin. Nutr. 63 (1) (2009) 39–47, https://doi.org/10.1038/sj.ejcn.1602907.
[38] L.M. Powell, F.J. Chaloupka, Y. Bao, The availability of fast-food and full-service restaurants in the United States: associations with neighborhood characteristics, Am. J. Prev. Med. 33 (4 Suppl) (2007) S240–S245, https://doi.org/10.1016/j.amepre.2007.07.005.
[39] N.A. Hawkins, T. Smith, L. Zhao, J. Rodriguez, Z. Berkowitz, K.D. Stein, Health-related behavior change after cancer: results of the American Cancer Society's studies of cancer survivors (SCS), J. Cancer Surviv. 4 (1) (2010) 20–32, https://doi.org/10.1007/s11764-009-0104-3.
[40] E. Bouwman, S.M.F. Pluijm, I. Stollman, V. Araujo-Soares, N.M.A. Blijlevens, C. Follin, et al., Perceived barriers and facilitators to health behaviors in European childhood cancer survivors: a qualitative PanCareFollowUp study, Cancer Med 12 (11) (2023) 12749–12764, https://doi.org/10.1002/cam4.5911.
[41] I.F. Pollack, Brain tumors in children, N. Engl. J. Med. 331 (22) (1994) 1500–1507.
[42] K.W. Wang, A. Fleming, D.L. Johnston, S.M. Zelcer, S.R. Rassekh, S. Ladhani, et al., Overweight, obesity and adiposity in survivors of childhood brain tumours: a systematic review and meta-analysis, Clin. Obes. 8 (1) (2018) 55–67, https://doi.org/10.1111/cob.12224.
[43] K.C. Oeffinger, A.C. Mertens, C.A. Sklar, Y. Yasui, T. Fears, M. Stovall, et al., Obesity in adult survivors of childhood acute lymphoblastic leukemia: a report from the Childhood Cancer Survivor Study, J. Clin. Oncol. 21 (7) (2003) 1359–1365, https://doi.org/10.1200/jco.2003.06.131.
[44] J. Cohen, D.G. Laing, F.J. Wilkes, A. Chan, M. Gabriel, R.J. Cohn, Taste and smell dysfunction in childhood cancer survivors, Appetite 75 (2014) 135–140, https://doi.org/10.1016/j.appet.2014.01.001.
[45] I. Skolin, Y.B. Wahlin, D.A. Broman, U.K. Koivisto Hursti, M. Vikström Larsson, O. Hernell, Altered food intake and taste perception in children with cancer after start of chemotherapy: perspectives of children, parents and nurses, Support Care Cancer 14 (4) (2006) 369–378, https://doi.org/10.1007/s00520-005-0904-6.
[46] G.T. Armstrong, M. Stovall, L.L. Robison, Long-term effects of radiation exposure among adult survivors of childhood cancer: results from the childhood cancer survivor study, Radiat. Res. 174 (6) (2010) 840–850, https://doi.org/10.1667/rr1903.1.
[47] K. Emmons, F.P. Li, J. Whitton, A.C. Mertens, R. Hutchinson, L. Diller, et al., Predictors of smoking initiation and cessation among childhood cancer survivors: a report from the childhood cancer survivor study, J. Clin. Oncol. 20 (6) (2002) 1608–1616, https://doi.org/10.1200/jco.2002.20.6.1608.