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Diet and Physical Activity in Childhood Cancer Survivors: A Review of the Literature

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Abstract

Treatment advances have led to a growing population of childhood cancer survivors. Many are at risk for developing treatment-related late effects. Diet and physical activity may affect levels of health risk. A number of papers have examined these behaviors in childhood cancer survivors. The purpose of this study was to provide a review and summary of the published studies in the areas of diet, physical activity, and related interventions among childhood cancer survivors. A systematic search was conducted for studies published prior to October 2009. Descriptive and intervention studies that included survivors of childhood cancers and a measurement of diet and/or physical activity were reviewed. Twenty-six manuscripts met criteria: ten addressed diet; 20 addressed physical activity, and six included intervention studies. Results suggest that childhood cancer survivors engage in health-promoting activities at rates comparable to the general population. Behavioral interventions have mostly targeted physical activity. Results, overall, are not encouraging, due primarily to difficulties recruiting and retaining participants. Although more rigorous studies are needed, recommendations for health-promoting behaviors should be a regular topic of discussion between health care providers and their childhood cancer survivor patients.

Keywords

Diet; Physical activity; Childhood cancer; Survivors

Introduction

In 2010, approximately 12,000 children will be diagnosed with cancer in the USA [1,2]. Fortunately, advances in treatment have led to dramatic improvements in survival, and over 75% of children with pediatric cancers survive disease-free for more than 5 years [3]. It is estimated that, as of January 1, 2005, there were 328,652 survivors of childhood cancer in the

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USA [4]. By 2010, it is expected that one in every 250 adults between the ages of 16 and 44 years will be a survivor of a childhood cancer [5].

Despite advances in treatment, numerous studies have documented the morbidity-related costs or late effects associated with childhood cancer treatments [6-8]. In a recent report from the Childhood Cancer Survivor Study, 62.3% of 10,387 survivors (mean age=26.6 years; range, 18.0 to 48.0) reported having at least one chronic health condition, of which 27.5% considered the condition to be severe and/or life-threatening [9]. In addition, 37.6% reported having at least two chronic health conditions, and 23.8% reported having three or more conditions [9]. In contrast, only 36.8% of siblings of survivors reported having one chronic health condition, of which 5.2% described it as severe or life-threatening; 13.1% reported having at least two conditions, and 5.4% reported having three or more conditions [9]. The most common chronic conditions were cardiovascular disease, renal dysfunction, severe musculoskeletal problems, second cancers, and endocrine abnormalities [9]. Of note, the incidence of chronic conditions in survivors did not appear to plateau but continued to increase over time [9].

Late effects are known to be associated with the type of cancer a survivor experienced in addition to the treatment type and treatment intensity received. Increasingly, the role of genetics and lifestyle are being explored as contributors to late effects. Specifically, some treatment-related late effects are believed to be exacerbated by high-risk health behaviors such as high-fat diets and physical inactivity [10-14]. There is empirical support for these relationships. For example, Hoffman et al. reported that decreased physical activity levels were associated with the development of metabolic syndrome among long-term survivors of pediatric sarcomas [10]. In a cross-sectional study of various cancer types, van der Sluis and colleagues identified calcium-deficient diets and lack of regular physical activity as important contributors to poor bone mass density and increased risk for osteoporosis [15]. Tillmann et al. reported that physical inactivity was related to lower lumbar bone mineral density and higher percent fat mass in survivors of acute lymphoblastic leukemia (ALL) [16].

Recognizing the risks and potential benefits associated with lifestyle, a number of studies have assessed health behaviors and/or examined the efficacy of health behavior interventions in long-term childhood cancer survivors. Four reviews have summarized some of these data [17-20]. One focused on smoking, alcohol use, recreational drug use, unsafe sex, and self-care [17]. A second reviewed health behaviors among cancer survivors in general, offering limited information on childhood cancer survivors [18]. The third summarized the results of a series of studies that were conducted by the Childhood Cancer Survivor Study (CCSS) regarding alcohol and tobacco use, smoking cessation, and physical activity [20]; and the fourth examined physical activity in children being treated for cancer, as well as childhood cancer survivors [19]. The current manuscript goes beyond any previous papers by providing a review and summary of the literature to date in the areas of diet, physical activity, and related interventions among childhood cancer survivors. The rationale for focusing on these behaviors is their direct contribution to the development or exacerbation of many of the long-term and late effects of childhood cancer treatment including: obesity, cardiovascular disease, osteoporosis, diabetes, hypertension, and second cancers. The purposes of this review are to provide investigators with a comprehensive overview and to describe the limitations of the current literature so as to inform the future development of rigorous research agendas that can address health behaviors and health promotion in childhood cancer survivors.

Data Sources

A systematic search was conducted for studies published any time prior to October 2009, in three databases: PubMed, Medline, and PsychInfo. The search consisted of the medical subject headings (MeSH) and text words: “childhood cancer” or “pediatric cancer” in combination with each of the following: “health behaviors,” “lifestyle,” “diet,” “nutrition,” “physical

activity," "exercise," and "intervention." All search results were limited to the English language. A secondary search was conducted by manually reviewing the reference sections of each identified manuscript.

Screening Criteria

Papers were selected for review if they met three inclusion criteria: (1) were published in a peer-reviewed journal; (2) included survivors of childhood cancer of any age; and (3) addressed diet and/or physical activity. Both descriptive and intervention studies were included in the review. Papers were excluded if they: (1) used a summative measure of multiple health behaviors without individual behavior results; (2) presented only qualitative data; (3) involved patients on treatment; or (4) were literature reviews or case studies.

The computer-based literature search in the three data-bases identified 327 papers that mentioned one or more of the MeSH headings or text words. An initial review of titles and abstracts narrowed the field to 72 papers that appeared to meet the three screening criteria described above. If an abstract was not available or did not contain sufficient information to assess initial eligibility, the manuscript was accessed and reviewed. A review of the full manuscripts for the 72 papers yielded 26 articles that met all inclusion and exclusion criteria. A search of these papers' reference sections did not identify any new manuscripts. Data from the final 26 studies were abstracted onto a word table including: authors/year and country, study design and sample characteristics, outcome variables and/or description of intervention, and results.

Results

Study Designs and Samples

Research addressing health behaviors in childhood cancer survivors has largely relied upon cross-sectional designs and targeted cohorts of survivors who are pre-adolescent/adolescent (9–18 years) or young adults (18+). These groups may be important to distinguish because they reflect different developmental stages and may also differ in the influences and societal norms that shape their health behaviors. This review addresses research with childhood cancer survivors regardless of age, recognizing that, across all age groups, there is limited empirical research.

Samples from the majority of reviewed studies were primarily white non-Hispanic, middle to upper income, and included mixed cancer diagnoses with varying times of survival. Only one study focused on racial/ethnic minorities [21], three studies considered race/ethnicity in their analyses [14,22,23], and six considered differences across diagnostic groups [22-27]. The consideration of diagnostic group could be important given that different treatment protocols affect risk for late effects and thus may impact decisions about health behaviors. The majority of studies excluded central nervous system (CNS) tumor survivors, contributing to the dearth of information about this particularly vulnerable subgroup.

Of the 26 studies, 18 were conducted in the USA, four in Europe (UK, Germany, and The Netherlands) [16,28-30], three in Canada [27,31,32], and one in Australia [26]. One of the US studies recruited via the Internet [33] and 12 recruited at individual hospitals [23-25,34-42]. Of these, four were conducted with patients from the St. Jude's Children's Research Hospital, three of which were conducted within the hospitals after completion of therapy (ACT) clinic [34,37,38,40]. Studies conducted at St. Jude's do not necessarily include the same cohort of patients and are not longitudinal in nature.

Five studies were based on data from participants in the CCSS [14,21,22,43,44]. The CCSS is a multi-institutional, longitudinal study of individuals ages 18 years and older who survived a

childhood cancer that was diagnosed before the age of 21 years [45]. All CCSS participants were diagnosed between the years 1970 to 1986, at one of 26 participating medical institutions. Baseline data were collected from over 10,000 survivors from 1994–1998; subsequent questionnaires were mailed out in 2000 and 2003, and there have also been ancillary studies with subgroups of the CCSS cohort [22,44].

Diet—Lifestyles that include high-calorie, high-fat, and low-fiber diets contribute to the development and maintenance of obesity, cardiovascular disease (CVD), and some cancers [46-49]. Furthermore, diets that are insufficient in key nutrients such as calcium and vitamin D are associated with the development of osteoporosis [11]. There are ten published studies that examine diet in childhood cancer survivors [16,24-26,28,37-40,43]. Results reflect the current culture of the USA with a common observation of unhealthful diets across *all* age groups (see Table 1). Of particular concern are low fruit and vegetable intake, low calcium intake, and high fat intake [16,24-26,38,39,43]. One study that used a validated measure of dietary intake reported that 84% of their adolescent and adult sample ate more than the recommended 30% of calories from fat; 21% ate the recommended five or more daily servings of fruits and vegetables, and less than 45% of adolescent survivors and 25% of adult survivors met guidelines for calcium intake [24]. Further description of dietary behaviors was offered in an ancillary study of the CCSS cohort that considered how the diets of adult survivors of ALL compared with the USDA Food Guide, the Dietary Approaches to Stop Hypertension (DASH) diet, and the 2007 World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) guidelines [25]. Average scores were 3.0 out of 8 for the USDA Food Guide, 3.6 out of 11 for the DASH diet, and 2.9 out of 7 for WCRF/AICR with lower scores reflecting poorer eating habits [25].

In comparison to adults, two studies suggested that pre-adolescents/adolescents survivors consume more healthful diets than adult survivors [24,38,40]. For example, Demark-Wahnefried reported that younger survivors were more likely than adult survivors to meet calcium guidelines and eat 5+ daily servings of fruits and vegetables [24]. Additionally, Mulhern et al. reported that nearly 60% of their pre-adolescent/adolescent sample ate balanced meals most of the time, compared with 48% of young adults [38]. It is not clear, however, if these results were due to positive parental influence, or, in fact, to biased parental reporting [38].

Correlates: A number of investigators explored predictors or correlates of dietary patterns, including age group, BMI, smoking status, cancer type, treatment, quality of life, health protection beliefs (defined as: compared with most other [children] young adults, how important do you think it is to keep [your son or daughter] as healthy as possible?), socioeconomic status, perceived vulnerability, and health locus of control [24,25,38,40]. Only younger-age, health protection beliefs, and higher SES were predictive of healthier eating patterns [24,38,40]. One small study of ALL survivors found that those treated with cranial radiation therapy (CRT) reported lower caloric intake than those who did not receive CRT [28].

Limitations of the Current Literature: Overall, the dietary research with childhood cancer survivors is methodologically weak. All studies were cross-sectional and only one included a control group. Only three used standardized measures of dietary intake [24,25,39], with others relying on single non-standardized items some of which queried about regular consumption of “nutritious diets” or “balanced meals” [37,38,40]. These terms were not operationally defined and thus were left to the interpretation of the respondent. Most studies had small samples, and thus results related to predictors and correlates may be inaccurate. No studies considered dietary intake among minority survivors. Future studies should address these deficits and broaden their scope to consider additional mediators and moderators.

Physical Activity—Physical activity, like diet, contributes to energy balance and thus is strongly related to weight status. In addition, there is a substantial body of evidence to support that participation in regular moderate-intensity physical activity can be protective against obesity, CVD, osteoporosis, diabetes, hypertension, and some cancers [50,51]. Twenty studies addressed physical activity [14,16,21-28,[31],[33],36-41,43,44]. Most found low levels of physical activity among survivors, particularly among adult survivors. On average, survivors were less likely to be active than non-cancer controls with reports of less than 50% of the adult samples engaging in regular physical activity or meeting guidelines for regular physical activity [14, 21,22,24,25,37,38,40]. In comparisons to the 2003 Behavior Risk Factor Survey Study (BRFSS) data, Ness et al. reported that 52.1% of CCSS participants did not meet CDC guidelines of 20 min vigorous activity at least 3 days a week or 30 min moderate activity at least 5 days a week, and 22.7% were inactive, compared with 47.3% and 20.0% of BRFSS participants, respectively [22]. A second CCSS report of physical activity across racial/ethnic groups found that Hispanic males were less likely to meet CDC guidelines and more likely to be inactive as compared with non-Hispanic white males. No other differences across racial/ ethnic groups were noted [21]. These CCSS data came from the 2003 follow-up survey.

Some studies report more healthful patterns among survivors. In a Web-based study, Finnegan et al. [33] found that over 80% of their well-educated, young adult sample reported that they met the CDC guidelines for physical activity. Similarly, data from an ancillary study of a subsample of the CCSS indicated that over 70% of their young adult sample exercised at least 30 min on at least 5 days per week [44].

In studies of adolescents, results were similarly inconsistent. Several studies reported that less than 50% of their samples were active [23,24,37], while others reported that 75% to 80% of their samples engaged in regular physical activity [38,40,41]. Although most studies of adolescents did not include control groups, Tillmann et al. reported lower levels of activity among survivors as compared with controls [16]. Of further note are the results of one study that examined activity across the cancer experience (prediagnosis, during treatment, and post-treatment); most adolescents reported that they decreased their physical activity after their diagnosis, and a significant subset did not return to their pre-diagnosis level of physical activity. Not surprisingly, adolescents who were inactive prior to their diagnosis remained inactive following treatment [27]. These results highlight the need for timely interventions to support activity in formerly active survivors, as well as those who are chronically inactive.

Correlates: A number of studies examined correlates of physical activity including demographics, BMI, diagnosis, treatment, other health behaviors, and cognitive and psychological factors. For other demographic variables, higher levels of activity among adult and adolescent survivors were associated with being male, of a younger age, being non-Hispanic white, and having more than a high school education [14,21-24,33,40]. In one small study, adequate insurance coverage was related to an increased likelihood of being involved in organized sports [23].

BMI and physical activity were inconsistently associated. In the overall CCSS sample, underweight and overweight were associated with inactivity and not meeting CDC guidelines for physical activity [22]. Similarly, obese ALL survivors in CCSS were less likely than normal weight ALL survivors to meet CDC guidelines [14]. However, a small study of adolescent survivors found no association between BMI and participation in organized sports [23].

A few studies considered the impact of specific cancer type or treatment modality received. Three studies found inactivity was more common among survivors of CNS tumors and osteosarcomas than other cancer types [22,24,26]. Similarly, CRT or amputation was associated with higher levels of inactivity in the CCSS [14,22]. Inconsistent results have been

reported in ALL with one study finding that survivors treated with radiation plus chemotherapy had lower levels of physical activity than those not receiving radiation [28], and a smaller study of ALL survivors finding no physical activity differences across treatment modalities [39].

Health behaviors such as diet and smoking have also been related to physical activity. In the CCSS, smokers were less likely than non-smokers to meet CDC guidelines for physical activity [22]. Additionally, in a study of adolescents and young adults, diet and physical activity were positively correlated for both age groups [38].

Cognitive and psychological variables related to physical activity have been explored in several studies. Constructs among adult survivors have included self-efficacy [33], autonomous motivation [33], physical activity cons [33], depression [22,41], belief that one's primary care physician was familiar with cancer-related problems [44], fears regarding future health [44], perceived stamina [44], and fatigue [44]. Among adolescents, parent–child conflict [41] and psychosocial well-being were related to physical activity [31]. Results for perceived vulnerability were inconsistent. Mulhern et al. [38] reported a significant relationship among pre-adolescents/adolescents (as reported by their parents), but not for the young adults, and Tyc et al. [40] found no association between perceived vulnerability and physical activity in a sample of 10–18-year-old survivors. Certainly, the influence of parental report must be considered in evaluating the inconsistency between these two studies.

Limitations of the Current Literature: The most significant limitation in the physical activity research conducted with childhood cancer survivors to date is the lack of objective physical activity measures. Although some studies used standardized measures of physical activity [39] or standardized items from the BRFSS/Youth Risk Behavior Surveillance System [14, 21,23,33,[37],38,40,41,43], only two studies used objective measures of physical activity such as accelerometers or pedometers [16,30]. Subjective self-report outcomes included hours/minutes of activity performed each week [38,40,43], time and intensity of activity [16,27,28], participation in aerobic activity (yes/no), participation in organized sports (yes/no) [23], and whether the participant was inactive, exercised regularly, or met current physical activity guidelines [14,22,24,31,33,39,41,44]. It is also important to note that physical activity guidelines or definitions of regular physical activity or "inactivity" differed between studies. In some, regular physical activity or inactivity followed CDC guidelines (moderate physical activity for at least 30 min on at least 5 days a week or vigorous physical activity for at least 20 min on at least 3 days a week) [14,21,22,33,41,44,52], while others used Department of Health and Human Services guidelines [43] (moderate physical activity for at least 30 min on at least 5 days per week) [53] or the surgeon general's guidelines [24] (≥1 h a day on most days of the week for adolescents and ≥30 min a day on most days of the week for adults) [54].

In addition to the lack of objective measurement of physical activity, other methodological limitations include: lack of non-cancer comparison groups, cross-sectional designs with a mix of diagnostic groups, and predominantly non-Hispanic white samples. There were exceptions; however, Oeffinger et al. (2001) and Florin et al. (2007) looked exclusively at adult survivors of childhood ALL [14,39]. Demark-Wahnefried et al. [24] examined physical activity levels between different diagnostic groups (central nervous system, lymphoma, and leukemia). In addition, Castellino et al. [21] focused on minority CCSS participants, while two other CCSS reports [14,22] considered race/ethnicity in their analyses of CCSS survivors.

Further limitations include the lack of studies that consider mode of activity especially across age and diagnostic groups. This information would be important to inform the development of interventions. Finally, certain subgroups of survivors are at higher risk for inactivity (i.e., osteosarcoma and CNS tumor survivors) and face unique barriers; thus, it will be important to understand more about their patterns and needs.

Diet and/or Physical Activity Interventions—Although health behavior interventions are common in non-cancer populations, it is only in the last two decades, as survival rates have improved, that efforts have widened to include cancer patients and survivors [24,55-57]. Six intervention studies target childhood cancer survivors: five target physical activity [29,30,32, 35,42] and one addresses multiple health behaviors [37].

The physical activity interventions ranged from 10 to 16 weeks in length. Two were conducted at a hospital [35,42], one in the community [29], one at a university [32], and one was home-based [30]. Three of the five studies [30,35,42] targeted adult survivors, while two targeted pre-adolescents and /or adolescents [29,32]. Outcomes varied across studies. Sharkey et al. focused on a number of cardiovascular-related variables including peak oxygen uptake, ventilator anaerobic threshold, as well as total exercise time and perceived exercise tolerance [42]. Takken et al. considered a number of fitness outcomes such as muscle strength, exercise capacity, and functional mobility [29]. Most studies relied on self-report measures of physical activity participation, although one used a pedometer to record steps per day [30]. Four studies included measures of fatigue [29,30,32,35]. The interventions typically involved once or twice weekly sessions that were 60–90 min in length. With the exception of the home-based intervention [30], these sessions were supervised. Aerobic training was the primary activity; however, two interventions also included strength and flexibility training [29,32]. Keats et al. also included an educational component for the first 8 weeks of their 16-week intervention [32]. Although the majority of interventions lacked any theoretical framework, Keats et al. based their intervention on the tenets of the theory of planned behavior, while Blauuwbroek et al. used goalsetting theory, as well as stages of change theory [30,32].

Overall, results of the physical activity interventions suggest only moderate success. Three of the five studies reported significant, yet modest, increases in physical activity post-intervention [30,32,42]; however, in the one study that included a 3-month follow-up, this increase was not maintained. The two studies that reported null findings struggled with participant attendance and retention [29,35]. All studies reportedly struggled with participant recruitment. Barriers to recruitment and retention included boredom, trouble maintaining the programs with other activities, fatigue, and for younger participants, parental support due to their concerns about pushing their children to do things that were unpleasant or challenging.

Perhaps one of the original interventions studies to be conducted with childhood cancer survivors, Hudson and colleagues initiated a multi-behavior education intervention based on the Health Belief Model at St. Jude's ACT clinic [37]. Efficacy of the intervention was evaluated in a randomized controlled study (the Protect Study) with 266 adolescent survivors (age 12–18years). The intervention included modules for each health behavior (smoking, sun protection, self-examination, diet, or exercise) that addressed attitudes, problem solving, and committing to a behavior for 1 year [37]. Survivors chose one behavior on which to focus. One-year results reflected no significant differences between the standard care and intervention groups in health knowledge, perceived susceptibility and seriousness, barriers to and benefits of health behaviors, or health behaviors (assessed by a summative measure of smoking, sun protection, self-examination, diet, and exercise). Noting the limitations of using a summative measure in this study, Cox and colleagues [34] re-examined intervention effects on individual health behaviors. In these analyses, the treatment group exhibited a significant increase in health knowledge, a decrease in junk food consumption and former smokers/non-smokers maintained smoking abstinence [34].

Limitations

The most prominent limitation of the diet and physical activity intervention literature in childhood cancer survivors is the lack of interventions that have been conducted and evaluated, particularly those that address diet. Additionally, the modest results and poor recruitment and

retention rates are also concerning. Interventions that were not sufficiently intensive may partially explain the modest results. However, small sample sizes may also be a contributor. It did not appear from the published intervention studies that any formative work, such as focus groups, was completed to help inform the interventions. Including survivors in the intervention planning phases may be important to consider when developing future interventions.

A final limitation is the absence of theoretical models in three of the interventions to provide a framework for the intervention content. In sum, the intervention literature is limited in quantity and quality, and thus little is known about the ideal content, duration, setting, mode of delivery, and timing of interventions to meet the needs of various age cohorts and also the needs of minority survivors.

Discussion

This paper summarizes the literature to date on the diet and physical activity patterns of childhood cancer survivors, as well as related interventions. This topic is of particular importance given the burden of late effects for many adult survivors of childhood cancers. Health promotion behaviors such as eating a healthy diet and participating in regular physical activity could offset some of the risks associated with these late effects of treatment [10-14]. Unfortunately, the evidence thus far suggests that childhood cancer survivors are no more likely to engage in health-promoting activities than individuals in the general population. Overall, few childhood cancer survivors consume diets that are “nutritious” or “balanced,” low fat, and include sufficient fruits and vegetables and adequate calcium intake [24,25,38]. In addition, many do not engage in regular physical activity that would include at least 30 min of moderate activity at least 5 days a week or 20 min of vigorous physical activity 3 days a week [22,24, 38-40,43]. Similar to healthy populations, the best predictors of eating a healthy diet and getting regular physical activity are socio-demographic variables including: younger age, female gender for diet, male gender for physical activity, higher education and socioeconomic status, and being non-minority.

This review highlights several limitations in the existing literature on diet and physical activity in childhood cancer survivors. Most notably, the strongest data come from one source—the Childhood Cancer Survivor Study. The strengths of the CCSS include its large sample, the breadth of topics addressed in the surveys, and the ability to track outcomes over time. Limitations include: reliance on mail-based surveys, no measure of dietary patterns; a sample drawn from academic institutions; limited representation of minorities; biased results given that only survivors who continue to complete the mail surveys are represented; and use of a sibling comparison group which controls for cancer treatments, but not necessarily the cancer experience or family influence on health behaviors. Overall, the research that has been conducted to date relies upon cross-sectional designs, small samples, no comparison groups, and subjective or non-standardized outcome measurement. Survivors of CNS tumors, osteosarcoma, and ethnic minority survivors are poorly represented in the literature. Finally, much of the research was conducted without the guidance of any theoretical framework. In addition, familial, community, or environmental variables that likely influence health behaviors were excluded from consideration.

Intervention research with childhood cancer survivors is in its infancy. Results thus far are discouraging with significant barriers to recruitment and retention and lack of any positive results. Future interventions could learn from these studies and address issues during the development stage. For example, obtaining parental support and addressing their concerns is critical to a successful intervention with children and adolescents. As with all interventions, they must be designed so they fit into the daily activities of the target population and hold their interest [29,35,58]. All intervention efforts thus far have targeted adolescent survivors, so little

is known about the feasibility and impact with other age groups. There is also no information on the value of tailoring interventions to fit risk profiles related to different diagnostic groups and/or treatment histories. Survivors of CNS cancers and osteosarcomas are in particular need of tailored physical activity interventions. Optimal timing for interventions is still unclear. However, given that health behaviors are often established early in life, early intervention could lay an important foundation for health promotion practices. The need for repeated intervention as survivors pass through different developmental phases also may be an important consideration. Methodological issues of the intervention studies are similar to those for the descriptive studies: biased samples in that they were recruited from specialized childhood cancer follow-up clinics, self-report measures, and lack of representation of diverse racial and ethnic groups. Ideally, future interventions will address these limitations, as well as include broader models of health behavior which consider familial, community, and environmental barriers and influences [59].

Limitations should be noted when considering the results of this review. First, the sample of manuscripts was limited to those that were published in peer-reviewed journals, were written in English, contained the searched key words, and were listed in the accessed databases. A second limitation is the potential for biased reporting by the authors. Although our intent was to present an unbiased view of study results, it is possible that unconscious bias ensued. Finally, the review is qualitative, with no inclusion of quantitative analyses or results. Despite these limitations, this review goes beyond the current literature and provides a comprehensive review of studies that have examined diet and physical activity in childhood cancer survivors.

Although further research on health behaviors and related interventions is needed, this should not preclude healthcare providers from assessing and making recommendations for health behaviors among childhood cancer survivors. Interest in survivors' health behaviors can communicate the value of practicing a healthy lifestyle and reflect providers' support of making efforts to this end. A number of private organizations [60,61] and federal agencies [62,63] provide guidelines for diet and physical activity that can promote health and decrease risk of chronic disease. At the very least, providers might encourage survivors to consume a predominantly plant-based diet that is low in fat, contains a variety of fruits and vegetables, and is sufficient in calcium intake [61]. They might also advise survivors to engage in regular physical activity such that they accumulate at least 30 min of moderate activity most days of the week [60]. Ideally, health care providers will regularly check in with patients about these behaviors, noting that they are an integral part of comprehensive survivorship care. As noted in the Institute of Medicine report "From Cancer Patient to Cancer Survivor, Lost in Transition," all patients completing treatment "should be provided with a comprehensive care summary and follow-up plan that is clearly and effectively explained…with recommendations regarding preventive practices and how to maintain health and well-being" [64].

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Table 1

Summary of studies on diet and physical activity in childhood cancer survivors

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
Butterfield, Park, Puleo et al., 2004 (CCSS[a]) [43]	Observational study of smokers in CCSS	$\bar{x}$ age, 30.7 years (SD=6.5)	Diet	
	N=541 adult survivors; no control group	89.5% non-Hispanic white (NHW)	Red meat consumption	67.7% ate more red meat than recommended
		0.7% African American (AA)	Multivitamin use	68.4% did not take multivitamin
		2.2% Hispanic (Hisp)	Physical activity	
		3.1% other	Minutes per week	28.9% engaged in less than 150 min/week
		4.4% not specified	Correlates/predictors	
		Dx: mixed	Gender	Women fewer risk behaviors than men
			Education	College grads fewer risk behaviors than non-HS grads
Blaauwbroek, et al., 2009 [30], The Netherlands	Intervention, pre–post	Median age, 29.8 years (SD=8.6)	Physical activity	
	N=46 adult survivors; no control group	No race/ethnicity data	No. steps pedometer	Increase steps 33% from baseline to week 3; 54% increase to week 10. No measurement at 36 weeks
	10-week home exercise program. Telephone counseling weeks 3, 6, and 9 to encourage increased activity or maintenance of activity. Based on goal-setting and stages of change theories	Dx: mixed	Fatigue	Significant improvement at 10 and 36 weeks
			Correlates/predictors	
			None	
Castellino et al., 2005 (CCSS) [21]	Observational, cross-sectional	$\bar{x}$ age, 26.5 years (SD=6.1)	Physical activity	
	N=8,767 adult survivors; no control group	86.6% NHW	% not meeting CDC guidelines[b]	NHW 59.8% male, 67.7% female; Hispanic 51.7% male, 64.0% female; AA 58.9% male, 72.0% female
		4.9% AA	Correlates/predictors	
		5.6% Hisp	Gender	Females more likely to be inactive
		Dx: mixed	Race/ethnicity	No between-race differences

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
Collett et al., 2007 [35]	Intervention, randomized control trial (RCT)	$\bar{x}$ age, 18 years (SD not provided)	Physical activity	
	N=36 survivors (information on sample sizes for two groups not provided)	No race/ethnicity data	Minutes per week of moderate/intense activity	No significant changes noted at post-intervention between or within groups
	12-week group exercise program focusing on cardiovascular fitness	Dx: mixed	BMI	
	Controls received written nutrition and physical activity information		VO^b max	
			Fatigue	
Cox, McLaughlin, Rai et al., 2005 [34]	Intervention, RCT re-analysis of Hudson et al., 2002 [37]	*N*=135 standard care	Diet	
St. Judes after completion of therapy clinic (ACT)	*N*=266 adolescent survivors	$\bar{x}$ age,14.96 years (SD=1.97)	Junk food consumption	Junk food consumption significantly decreased in the intervention group
		84% NHW;13% AA; 2% His		
		Dx: mixed		
	No control group	*N*=131 intervention		
		$\bar{x}$ age, 15.09 years (SD=1.90)		
		86% NHW; 14% AA; 0% Hisp		
		Dx: mixed		
Cox et al. 2009[44]	Observational, cross-sectional;	$\bar{x}$ age, 30.98 years (SD=7.5)	Physical activity	
CCSS survey ancillary study	*N*=838 adult survivors	74.4% NHW	% meeting CDC^b guidelines in last month	75.3% of males; 74.8 of females met guidelines
	No control group	7.7% AA	Correlates/predictors	
		11.5% Hisp	Cancer-related pain, anxiety, fatigue, and stamina	All negatively influence physical activity for both males and females
		6.1% other	Gender	Genders differ in terms of factors that predict physical activity in past month: females: greater stamina, less fatigue, and higher levels of aerobic activity predict more frequent physical activity; and males:

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
				perception that their PCP was familiar with cancer-related problems, greater fear regarding future health, more education, and higher levels of aerobic activity predict more frequent physical activity
		Dx: mixed		
Demark-Wahnefried et al., 2005 [24]	Observational, cross-sectional;	*N*=87 (Ad) $\bar{x}$ age, 14.9 years (SD=1.9)	Diet	
		82% NHW and 18% other	% dietary fat of daily kilocalories	$\bar{x}$ % fat (SD), 33.7% (3.7%) Ad; 33.5% (4.7%) adult
	N=209 pre-adolescent/adolescent (Ad) and adult survivors	Dx, 48% CNS; 9% lymphoma; and 43% leukemia	Low-fat diet	% following low-fat diet, 13.3% Ad; 20.6% adult
	No control group		Fruit and vegetable (F&V)	$\bar{x}$ F& V servings/day, 3.4 (3.0) Ad; 3.5 (2.7) adult
			Five a day	% eating ≥5 servings/day, 21.8% Ad; 19.7% adult
			RDA calcium	% meeting guidelines, 24.4% Ad; 42.2% adult
		N=122 adults	Physical activity (PA)	
		$\bar{x}$ age, 24.2 years (SD=4.0)	% meeting surgeon general's guidelines[C]	43.1% Ad; 55.1% adult
		87% NHW	Correlates/predictors	
		Dx, 38% CNS; 29% lymphoma; 33% leukemia	Age group	Ad more likely to exercise, meet daily calcium guidelines, and have 5+ daily servings of F&V
			Race, gender	No significant differences by race or gender
			Diagnosis (Dx)	CNS less likely to meet exercise guidelines than leukemia or lymphoma survivors. No assoc for diet
			Quality of life (QOL)	Significantly associated w/ PA, but not diet
Elkin, Tyc, Hudson et al., 1998 [23]	Observational, cross-sectional	*N*=127 organized sport	Physical activity	
	N=251 adolescent survivors	$\bar{x}$ age, 14.2 years (SD=1.7)	Participation in org sports	51%, (*n*=127; 61.4% male, 38.6% female)
	No control group	80.3% NHW; 19.7% AA; and 0.0% His	Participation in non-org forms of exercise	83%; 95% of sports group and 70% of non-sports group
		Dx: mixed	Correlates/predictors	
			Gender	More males than females participated in org sports

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
		N=124 non-org sport	Age, race, SES, diagnosis, BMI, smoking, and alcohol	Org sports/non-org sports groups not different in age, race, SES, diagnosis, BMI, smoking, or alcohol use
		$\bar{x}$ age: 14.5 years (SD=1.8)	Insurance, healthcare	Org sports group more likely to have adequate health insurance and have local MD monitoring their health
		83.5% NHW; 4.5% AA; and 2.0% Hisp		
		Dx: mixed		
Evans and Radford, 1995 [36]	Observational, cross-sectional	$\bar{x}$ age, 20 years (16–30 years)	Physical Activity	
	N=48 adolescent and adult survivors	*N*=32, 5 years< survivors	Competitive sports	51% of all survivors vs. 55% of siblings took part in competitive sports
	N=38 sibling controls	N=16, 5 years> survivors	Mobility	8% of long-term survivors reported problems with mobility and majority could not resume team sports
		No race/ethnicity data	Correlates/predictors	
		Dx: mixed	None	
		$\bar{x}$ age, 21 years (16–30 years)		
		No race/ethnicity data		
Finnegan et al., 2007 [33]	Observational, cross-sectional	$\bar{x}$ age, 24 years (SD=5)	Physical activity	
	N=117 adult survivors	95% NHW; 3% AA; 10% Hisp	CDC guidelines[b]	81% active; 19% inactive
	No control group	Dx: mixed	Correlates/predictors	
			Gender	Males more likely than females to be active
			Autonomous motivation	Higher scores more likely to be active
			Self-efficacy	Higher self-efficacy more likely to be active
			Physical activity cons	Higher scores less likely to be active
			Self-reported worries	Not related to physical activity
Florin et al., 2007 [14] (CCSS)	Observational, cross-sectional	*N*=2,648 ALL survivors	Physical activity	
	N=2,648 adult survivors	$\bar{x}$ age, 28.7 years (18–44 years)	CDC guidelines[b]	Survivors more likely than controls to not meet guidelines (52.8% survivors vs 48.2% controls, *p*<

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
				0.001) and to be inactive (23.0% survivors vs 20.3% controls)
		88.4% NHW; 3.1% AA; and 5.2% Hisp	Correlates/predictors	
			Demographics	Female gender, older age, and being a racial/ethnic minority all associated with higher likelihood of not meeting CDC guidelines
		Dx, 100% ALL	BMI	Overweight and obesity associated with higher risk of not meeting guidelines
	Comparison group: BRFSS 2003	BRFSS 2003 controls	Treatment history	CRT associated with higher likelihood of not meeting CDC guidelines and being inactive
		N=110,623		
		$\bar{x}$ age: not provided (range, 18–44 years)		
		72.5% NHW; 9.4% AA; and 10.6% Hisp		
Hudson, Tyc, Srivastava et al., 2002 [37]	Intervention, RCT[b]; standard care vs standard care +interv	$\bar{x}$ age, 14.96 years (SD=1.97)	Diet, physical activity	
St. Jude's after completion of therapy clinic (ACT)	*N*=266 Pre-adolescent/adolescent survivors	*N*=135 standard care	Baseline	
	Standard care:	84% NHW; 13% AA; 2% Hisp	Diet	40% ate nutritious diets
	Breast or testicular self-exam training	Dx: mixed, ALL and solid tumor	Physical activity	52% performed regular aerobic exercise
	Targeted late effects screening		Post-intervention	
	Clinical assessment by MD/PNP		Diet, physical activity	No significant differences in change scores b/w groups
	Late effects risk counseling		Correlates/predictors	
	Standard care±interv:	*N*=131 Interv	Gender	Females in intervention significantly greater increases in health knowledge than males; no gender differences in control group
	Distribution/discussion of written "after completion	86% NHW and 14% AA		

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
	of therapy" summary			
	Health behav training;			
	Commitment to chosen health goal for 1 year	Dx: mixed, ALL and solid tumor		
	Phone follow-up at 3+6 months to reinforce behav training			
Keats et al., 1999 [31] Canada	Observational, cross-sectional	$\bar{x}$ age, 17.3 years (SD=1.65)	Physical activity	
	N=54 adolescent survivors	No race/ethnicity data	Leisure time physical activity patterns: pre-diagnosis (Dx), during treatment (Tx), and post-treatment	81.1% active pre-Dx; 32.1% active during Tx; 71.4% active post-Tx; 27% active at all three time points
	No control group	Dx: mixed	Organized sports (OS) participation at three time points	67.9% in OS pre-Dx; 28.3% in OS during Tx; 34.0% in OS post-Tx; 14% in OS at all three points
			Correlates/predictors	
			Psychosocial well-being	Not related to leisure time exercise, but those who maintained organized sports post-treatment had better psychosocial well-being
Keats, 2006 [27] Canada	Observational, cross-sectional	$\bar{x}$ age, 17.3 years (SD=1.2)	Physical activity	
	N=97 adolescent survivors	No race/ethnicity data	Leisure time physical activity patterns	84.5% active pre-Dx; 26.4% active during treatment; 73.6% active post-Tx; 20% active at all three time points
	No control group	Dx: mixed	Leisure Score Index (LSI)	Significant decrease in total LSI from pre-Dx to during Tx
			Return to pre-Tx activity	Physical activity levels were not regained post-Tx
			Intensity	Frequency of vigorous and moderate activity remained decreased following treatment
			Correlates/predictors	
			Demographic/medical	Age, education, Dx, and Tx showed no significant relationship to physical activity
Keats, 2008 [32]	Intervention, pre–post	$\bar{x}$ age, 16.2 years (SD=1.6)	Physical activity	
	N=10 adolescent survivors	No race/ethnicity data	Metabolic equivalent of task hours per week	Significant increase at 16 weeks, but not maintained at 3- or 12-month follow-ups
	No control group	Dx: mixed	Fitness	Significant improvements in upper body strength and

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
				flexibility at 16 weeks. No improvements at 16 weeks in cardiorespiratory endurance
	16-week University-based exercise program; 8 weeks exercise+education; 8 weeks exercise only; based on Theory of Planned Behavior		Quality of Life (PedsQL)	Improved QOL at 16 weeks and 3- and 12-month follow-ups
			Fatigue (PedsQL-MFS)	No change at 16 weeks, improved at 3- and 12-month follow-ups
			Correlates/predictors	
			None	
Mayer et al., 2000 [28] Germany	Observational, cross-sectional	*N*=25 cranially irradiated (CRT)	Diet	
	N=39 adolescent and adult survivors	$\bar{x}$ age, 14.6 years (SD=0.5)	Caloric intake/24-h recall	Significantly higher caloric intake among no CRT
	No control group	*N*=14 non-irradiated (no CRT)	Physical activity	
		$\bar{x}$ age, 13.6 years (SD=0.5)	Physical activity level	No difference between CRT and no-CRT
		No race/ethnicity data	Correlates/predictors	
		Dx: mixed	None	
Mulhern et al., 1995 [38]	Observational, cross-sectional	*N*=110 parents reporting for pre-adolescent (Ad)	Diet	
St. Jude's ACT Clinic	*N*=150 Pre-adolescent/adolescent and adult survivors	Median age, 13.5 years (range, 9.5–17.9)	% eating balanced meals	Always, 16.4% Ad, 17.5% YA; most times, 58.2% Ad, 47.5% YA; sometimes, 19.1% Ad, 27.5% YA; seldom, 4.6% Ad, 5.0% YA; never, 0.9% Ad, 2.5% YA
	No control group	88.2% NHW; 10.0% AA; and 1.8% other	Physical activity	
		Dx: mixed	Hours per week	>6 h, 40.9% Ad, 17.5% YA; 5–6 h, 15.5% Ad 7.5% YA; 3–4 h, 24.6% Ad, 22.5% YA; 1–2 h, 12.7% Ad, 35% YA; <1 h, 6.4% Ad, 17.5% YA
			Correlates/predictors	
		N=40 young adult (YA)	Age group	YA more likely to be sedentary than Ad (p<0.001)

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
		Median age, 22.1 (range, 18.0–29.5 years)	Health protection beliefs	Positively correlated with diet and physical activity for YA, but not Ad
		100% NHW	BMI	No association
		Dx: mixed		
Ness et al. 2009 [22] (CCSS)	Observational, cross-sectional	Age: minimum 18 years; 82% (18–39 years)	Physical activity	
	N=9,301 adult survivors	NHW 89%; AA 3.6%; Hisp 4.2%; oth 2.8%; unknown 0.4%	CDC guidelines[b]	52.1% surv vs. 46.9% siblings did not met guidelines
		Dx: mixed	Inactive lifestyle	22.7% surv vs. 14% sib met inactive lifestyle def
	N=2,886 sibling control group	Age: minimum 18 years; 72% (18–39 years)	Correlates/predictors	
		NHW 86.6%; AA 2%; Hisp 2.8%; oth 5.4%; and unknown 0.6%	Race/ethnicity	Minorities more likely to not meet guidelines and be inactive
			Demographics	AA race, female gender, older age, lower educational attainment, underweight or obese status, smoking, and higher depression (BSI) associated with inactivity
			Diagnosis and treatment	CNS tumor and osteosarcoma survivors more likely to report inactive lifestyle compared with other diagnoses, especially those that underwent CRT or an amputation
Oeffinger et al., 2001 [39]	Observational, cross-sectional	Median age, 20.9 years (18–32 years)	Diet	
	N=26 ALL adult survivors	77% NHW; 12% AA; and 12% Hisp	MEDFICTS (measures cholesterol lowering diet)	Median MEDFICTS score=71, equivalent to a diet that does not lower cholesterol levels
	No control group	Dx: ALL only	Physical activity	
			Paffenbarger Physical Activity Index	Median physical activity index=1,328 kcal/week, 35% had an index <1,000 equivalent to a sedentary lifestyle
			Correlates/predictors	

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
			Treatment (chemo alone vs chemo+CRT)	No difference in physical activity between those who received CRT and those who did not
Reeves, 2007 [26] (Australia)	Observational, cross-sectional	$\bar{x}$ age, 21 years (SD=4)	Diet	
	N=28 adult survivors	No race/ethnicity data	Fruit and veg servings/day	21% of survivors ate recommended servings of fruits/ day; 4% ate recommended servings of veg/day
		Dx: CNS, leukemia, and lymphoma only	Physical activity	
			% meeting recommended activity	36% reported recommended activity
			% sedentary	11% reported no activity
			Correlates/predictors	
			Dx	CNS and leukemia survivors less likely to be active compared with lymphoma survivors
Robien, 2008 [25]	Observational, cross-sectional	$\bar{x}$ age, 29.9 years (SD=7.3)	Diet	
	N=72 adult survivors	97% NHW	Daily kilocals	2,529 kcal/day for men and 1,990 kcal/day for women
		Dx: ALL	Percent fat	49% reported ≤30% of calories from fat
			Percent saturated fat	44% reported ≤10% of calories from sat fat
			% exceeding recommended sugar intake	86% exceeded rec. mean sugar intake by USDA rec.
			Sodium intake	35% reported sodium intakes >2,400 mg/day
			% meeting recommended fiber intake	10% met sex-specific fiber intake
			% meeting recommended daily grain intake	0% met any daily grain intake guideline
			Average diet scores	2.9/7 points (range, 0-6) for WCRF/AICR; 3.6/11 (0.5–7.0) for DASH diet; and 3.0/8 (1.0–6.0) for USDA Food Guide
			Physical activity	
			Leisure time activity	9.7% no activity; 72.2% 1–149 min/week; 18.1% ≥150 min/week
			Guidelines	18% met recommended for 30 min of physical activity 5 days per week
			Correlates/predictors	

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
			BMI	Not associated with compliance with DASH diet or USDA Food Guide
Sharkey et al., 2007 [42]	Intervention, pre–post	$\bar{x}$ age, 19 years (SD=3)	Physical activity	
	N=12 adolescent/adult survivors	No race/ethnicity data	Perception of exercise ability	All reported improved exercise ability.
	12-week, twice weekly hospital-based cardiac rehab program. At week 7, once weekly home exercise program added	Dx: mixed	Percent body fat	No change in percent body fat
			Spirometry	No changes in spirometry
			Total exercise time	Exercise time increased an average of 13%
			Peak oxygen uptake	No significant changes
			Peak heart rate	
			Peak stroke volume index	
			Minimal systemic resistance index	
Takken, 2009 [29]	Intervention, pre–post program	$\bar{x}$ age, 9.3 years (SD=3.2)	Physical activity	
The Netherlands	*N*=16 ALL pre-adolescent/adolescent survivors	No race/ethnicity data	Baseline and post-intervention	
	No control group	Dx: ALL	BMI	No significant changes
	12-week community-based exercise intervention (aerobic and strength training); twice weekly at physical therapist, once weekly at home		Muscle strength	
			Functional mobility	
			Cardio-pulmonary fitness	
			Fatigue	
			Correlates/predictors	
			None	
Tercyak, Donze Prahlad et al., 2006 [41] baseline data Survivor Health and Resilience Education (SHARE) Program	Observation, cross-sectional	$\bar{x}$ age ,14.2 years (SD=2.4)	Physical activity	
	N=75 adolescent survivors	75% NHW and 25% other	Insufficient physical activity (CDC[b])	20% reported insufficient physical activity

Author/year	Design/intervention	Sample	Variables/outcomes	Results/outcome
	No control group	Dx: mixed, 52% Leukemia	Correlates/predictors	
			Demographics	Older patients higher behavioral risk factor scores
			Depression and parent–child conflict	Patients with depressive symptoms and parent–child conflict exhibited more behavioral risk factors
Tillmann, 2002 [16] UK	Cross-sectional	$\bar{x}$ age, 10.7 years (SD=2.1)	Diet	
	N=28 pre-adolescent/adolescent ALL survivors (surv)	No race/ethnicity data	Dairy product consumption	High, 57.1% surv and 71.4% cntrl; moderate, 39.3% surv and 25% cntrl
	N=28 age-matched healthy controls (cntrl)	Dx: 100% ALL	Physical activity	
		$\bar{x}$ age, 10.4 years (SD=3.1)	Weekly activity score (higher=more activity)	Significantly lower in surv vs cntrl
		No race/ethnicity data	Accelerometer	No results reported for surv vs cntrl
			Correlates/predictors	
			None	
Tyc et al., 2001, (mpo) [40]	Cross-sectional	$\bar{x}$ age, 13.7 years (SD=2.29)	Diet	
St. Jude's Research Hospital	*N*=46 adolescent survivors	94% white	Frequency of consuming balanced meals	Never, 2.2%; seldom,13.3%; sometimes, 22.2%; most times, 46.7%; always, 15.6%
	No control group	Dx: mixed	Physical activity	
		No CNS	Hours exercise/week	<1, 8.9%; 1–2, 15.6%; 3–4, 22.2%; 5–6, 24.4%; >6, 28.9%
			Correlates/predictors	
			Demographics	Younger age, higher SES more positive health behav
			Perceived vulnerability	Not associated
			Perceived importance of health protective behaviors	Not associated
			Health locus of control	Not associated

[a] Childhood Cancer Survivorship Study

[b] CDC Physical Activity Guidelines: vigorous activity ≥20 mins≥3 days per week or moderate activity≥30 mins≥5 days per week

[c] Surgeon General's Guidelines: ≥1h a day on most days of week for adolescents and ≥30 min a day on most days of week for adults