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Active Transportation in Adult Survivors of Childhood Cancer and Neighborhood Controls

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Abstract

Purpose—Childhood cancer survivors (CCS) are at high risk of treatment-related late effects, including cardiovascular disease and diabetes, which can be exacerbated by inadequate physical activity (PA). Previous PA interventions targeting CCS have focused on the domain of leisure-time/recreational PA. Active transportation, another domain of PA, has not been described in CCS. Therefore, this study aimed to identify active transportation behaviors, barriers, and correlates in adult CCS.

Methods—We recruited 158 adult CCS and 153 controls matched on age, sex, and neighborhood for a survey regarding active transportation behaviors and perceptions. Linear and logistic regression models accounting for correlation among matched participants were used.

Results—Adult CCS engaged in similar levels of active transportation as controls (2.72 vs. 2.32 hours/week, $P=0.40$) despite perceiving greater health-related barriers (1.88 vs. 1.65 (measured on four-point Likert scale), $P=0.01$). Marital/relationship status (odds ratio (OR)=0.30, 95% confidence interval (CI)=0.11–0.81), planning/psychosocial barriers (OR=0.15, 95% CI=0.04–0.53), and perceived neighborhood walkability (OR=2.55, 95% CI=1.14–5.66) were correlates of active transportation among adult CCS, while objective neighborhood walkability (OR=1.03, 95% CI=1.01–1.05) was a correlate among controls.

Conclusions—Results suggest adult CCS and controls utilize active transportation at approximately equal levels. Factors other than health, including perceived neighborhood walkability, appear to influence active transportation behaviors to a greater degree in adult CCS.

Implications for Cancer Survivors—Interventions might consider promoting active transportation as a way to incorporate more PA into the daily lives of adult CCS. Such interventions will not be widely successful, however, without existing or improved neighborhood walkability/bikeability.

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CONFLICT OF INTEREST

ME Slater, AS Kelly, KT Sadak, and JA Ross declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Keywords

childhood cancer survivors; cancer survivorship; active transportation; neighbourhood walkability; physical activity

INTRODUCTION

Over the past several decades, significant advances in the treatment of childhood cancer have dramatically improved rates of survival. Currently, over 83% of pediatric cancer patients survive for five years or longer [1]. As the number of long-term childhood cancer survivors (CCS) has continued to increase to more than 375,000 individuals in the United States, attention has shifted towards the prevention of adverse late effects. CCS are at an increased risk for numerous chronic health conditions often linked to treatment toxicities, including obesity, osteoporosis, type 2 diabetes, and cardiovascular and pulmonary disease [2]. The cumulative prevalence of any chronic health condition at age 45 has been estimated to be as high as 95.5% among CCS [2], and CCS are seven times more likely to die from cardiovascular disease than similar aged individuals from the general population [3].

These late effects may be exacerbated by the low levels of physical activity (PA) commonly observed among CCS. On average, CCS are less likely to be active than non-cancer controls, and fewer than half engage in regular PA or meet guidelines for regular PA [4]. For example, 52.1% of adult CCS from the Childhood Cancer Survivor Study did not meet the Centers for Disease Control and Prevention guidelines for PA (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 participants from the 2003 Behavioral Risk Factor Surveillance System, respectively [5]. Also among adult CCS from the Childhood Cancer Survivor Study, not participating in any self-reported leisure-time PA in the previous month was associated with obesity, hypertension, and impaired glucose tolerance [6]. Although the most frequently reported barriers to PA among young adult CCS are also commonly reported by healthy young adults (e.g., being too tired or too busy, not belonging to a gym, or preferring to do other activities such as reading or watching television), young adult CCS have reported experiencing barriers that differ from those experienced by healthy populations, including physical limitations (e.g., being wheelchair bound or bedridden) and suffering from pain or the side effects of illness [7]. Adult CCS and controls were included in the current study in order to examine such differences between these populations.

Only a limited number of PA interventions have been conducted that specifically targeted CCS in the post-treatment setting [8]. All have been short term (16 weeks or less), have focused on leisure-time/recreational PA, and have experienced problems with recruitment, attendance, retention, and maintenance of increased PA levels [4,9–11]. These interventions might be improved by incorporating innovative strategies to increase and sustain PA. One such strategy includes targeting often-overlooked forms of PA, such as active transportation. Active transportation (i.e., any self-propelled mode of transportation to get from one place to another, including walking or biking to work, school, stores, etc.) [12] is a domain of PA that has not yet been examined in CCS. All-cause mortality, obesity, type 2 diabetes,

hypertension, low cardiorespiratory fitness, and incidence of myocardial infarction have been inversely associated with active transportation among the general population [13–15], and previous intervention studies have suggested that encouraging active transportation may be an effective strategy for increasing total activity [13,16,17]. Notably, CCS (< 16 years of age) have been found to be 5 times more likely than sibling controls to report physical performance limitations in sports [18] and may therefore benefit from alternative PA options (e.g., walking) that can be incorporated into their daily lives. Supporting evidence from a study of adult breast cancer survivors showed that sports participation declined from 64.5% before diagnosis to 41.3% one year after surgery, while walking for pleasure or transportation increased from 89.7% before diagnosis to 93.2% one year after surgery [19].

To examine active transportation for the first time in CCS, we conducted the Transportation-Related Activities of Childhood Cancer Survivors (TRACCS) study. It was hypothesized that compared to matched neighborhood controls, adult CCS would report engaging in lower levels of active transportation, would report experiencing more barriers to active transportation, and would perceive their neighborhood environment as less walkable because individuals who are more sedentary tend to underestimate the walkability of their own neighborhoods [20,21]. We also anticipated that health-related barriers, in particular, would be a significant correlate of active transportation in adult CCS.

MATERIALS AND METHODS

Study Design and Participants

The TRACCS study was a cross-sectional survey of adult CCS and matched neighborhood controls. It was approved by the Institutional Review Board Human Subjects Committee at the University of Minnesota. CCS were identified through patient databases from the University of Minnesota Childhood Cancer Survivor Program and general Hematology/Oncology clinics. Of note, the University of Minnesota is one of 68 National Cancer Institute (NCI)-designated cancer centers, which, compared to non-NCI centers, are more likely to perform more complex procedures and treat patients who are younger, white, and have fewer comorbidities [22]. All participants for the CCS sample had provided written informed consent to be listed in clinic databases and contacted about future non-therapeutic studies. CCS aged 18 to 45 years who were diagnosed at least three years prior to the study with any form of pediatric (0–21 years of age) cancer, were not currently undergoing intravenous chemotherapy or radiation treatment, had a mailing address in the United States, and were able to complete a questionnaire in English were eligible to participate. The decision to include individuals up to age 45 was based on evidence that cardiorespiratory fitness declines at an accelerated rate after age 45 [23] and on the lack of a sufficient number of individuals over age 45 to facilitate a separate analysis of that group.

Controls were identified using lists of randomly selected names and addresses generated from infoUSA services from Infogroup (available at: <http://www.infousa.com>) and were matched to adult CCS (goal of one or more controls per adult CCS) on sex, age (within five years), and neighborhood (within a one mile radius unless closest eligible control lived more than one mile away). For adult CCS living in a rural area without a matched control within one mile, we used an expanded radius of up to four miles. Eligible control participants were

18 to 45 years of age, had no history of cancer as a child or adult, and were able to complete a questionnaire in English.

Of the 531 eligible adult CCS identified, 74 could not be located. The remaining 457 were contacted by mail, and completed questionnaires were obtained from 161 (35%). Of the 1364 potentially eligible controls identified, 180 could not be located. The remaining 1184 were contacted by mail, and completed questionnaires were obtained from 215 (18%). Three adult CCS (currently undergoing chemotherapy and/or radiation treatment) and 62 controls (incorrect age or address, and/or had a history of cancer) were determined ineligible after completing the questionnaire, leaving a final study population of 158 adult CCS and 153 controls. Of the 130 adult CCS with at least one matched control, 112 (86%) were located within a one mile radius of their control(s).

Data Collection

Self-reported active transportation behaviors and perceptions as well as demographics and other potential covariates (identified as known or potential covariates in prior active transportation studies) were ascertained via mailed paper questionnaire or over the phone with a trained interviewer (one participant). There were two versions of the TRACCS questionnaire, one for adult CCS and one for controls. The bulk of these two questionnaires consisted of modified versions of the 7-item International Physical Activity Questionnaire (IPAQ – short, self-administered version) [24], the 6-item transportation portion (Part 2) of an IPAQ (long, self-administered version) adapted for assessing seasonal variations in PA [25], the 18-item sections E., F., and V. from the Active Where? Study adolescent survey [26], and the unmodified 23-item section B. from the Neighborhood Environment Walkability Scale (NEWS) [27]. Both versions of the TRACCS questionnaire were pilot tested locally with 2 adult CCS and 8 controls prior to participant recruitment.

We modified the IPAQ to obtain usual transportation-related activity levels (i.e., bicycling and walking done in order to travel to and from work, to do errands, or to go from place to place) and other activity levels (occupational, household, and leisure-time domains combined) in summer, winter, and fall/spring to account for the seasonal variability in behavior typical of Minnesota and other Midwest states [28]. An example question set from the TRACCS survey is as follows: “3. During a usual week, on how many days do you bicycle to go from place to place? In summer: ___days per week; In winter: ___days per week; In spring/fall: ___days per week. 4. How much time do you usually spend on one of those days to bicycle from place to place? In summer: ___hours and ___minutes per day; In winter: ___hours and ___minutes per day; In spring/fall: ___hours and ___minutes per day.” On question 3, participants were also given the option to check a box indicating “No bicycling from place to place” with instructions to skip ahead to question 5. Activity levels were averaged over the four seasons to obtain usual hours per week of active transportation and non-transportation PA over the past year. Graff-Iversen et al. used similar methods in the use and validation of an IPAQ adapted for seasonal variation [25]. Intraclass correlation (ICC) reliability coefficients for the original IPAQ range from 0.78 to 0.94 [29]. Correlations between accelerometer-measured and IPAQ-measured physical activity are low (<0.4) but are reportedly a sign of fair criterion validity [29].

Sections E., F., and V. of the Active Where? adolescent survey inquire about barriers to walking and biking to stores/restaurants, parks, and school, respectively. We modified the text slightly for age-appropriateness (i.e., included gyms/workout facilities and parks rather than parks only and work and school rather than school only). Based on evidence from Arroyave et al. [7], one additional subscale containing two health-related items (feeling too tired/fatigued and being limited by a physical or medical condition) was added to assess whether adult CCS disproportionately experience barriers potentially related to their disease and/or treatment. Individual items were grouped into four subscale scores (means of individual items) for analysis: environmental, planning/psychosocial, safety, and health. Participants could agree or disagree according to a four-point Likert scale (1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree) as to whether a particular barrier made it difficult to actively travel to a certain type of destination, thus a higher subscale score indicates a greater barrier to walking or cycling. In a previous study, ICC values for test-retest reliability ranged from 0.40 to 0.80 for individual items and from 0.56 to 0.81 for the original environmental, planning/psychosocial, and safety subscale scores [30]. Subscale scores have also demonstrated acceptable internal consistency (Cronbach's alphas 0.70–0.86) and good validity (t-tests showed those who walked/cycled reported significantly lower scores than those who did not walk/cycle).

The NEWS was designed to measure perceived neighborhood walkability; in other words, residents' perceptions of the environmental attributes of their neighborhood that are hypothesized to be related to active transportation [31]. The proximity to stores and facilities subscale (section B) was included in the TRACCS questionnaire. Subscale scores can range from 1 to 5, with higher scores indicating greater perceived walkability. Although the NEWS was not specifically designed to measure bikeability (or other types of active transportation such as rollerblading, skateboarding, etc.), section B assesses both perceived walkability and bikeability in terms of proximity to destinations. Henceforth, the terms 'walkability' and 'walkable' should be interpreted as including all types of active transportation, not just walking. The test-retest ICC for this subscale score was 0.78, and construct validity has been demonstrated through statistically significant differences between responses from residents of objectively defined high-walkability versus low-walkability neighborhoods [27].

An objectively measured neighborhood walkability score, called Walk Score, was obtained on a publicly available website (available at: <http://www.walkscore.com>). Walk Score uses a geography-based algorithm to calculate walkability based on distance to 13 categories of amenities (e.g., grocery stores, coffee shops, restaurants, bars, movie theaters, schools, parks, libraries, bookstores, fitness centers, drugstores, hardware stores, clothing/music stores); geographic data is regularly updated by the Google application programming interface [32]. Each category is weighted equally and points are summed and normalized to yield a score from 0 to 100, with higher scores indicating greater walkability. Walk Score has been found to be valid and reliable for estimating access to nearby walkable amenities [33,34]. Walk Scores were obtained for all participants and non-participants, and participants' scores were compared to perceived walkability (i.e., NEWS proximity subscale).

Statistical Analysis

All analyses were conducted with SAS version 9.2 (SAS Institute, Inc., Cary, NC). A two-sided P -value <0.05 was considered to be statistically significant. Standard tests for outliers, multicollinearity, and other model assumptions were performed, and a variance inflation factor (VIF) >2.5 was considered to be evidence of multicollinearity in this analysis. Because there were minimal missing data ($<9\%$ missing in multivariable models) distributed similarly among adult CCS and controls, complete case analysis was used [35].

Descriptive statistics were expressed as frequencies and percents for categorical variables or mean $\pm$ standard error (SE) for continuous variables. Correlations between perceived and objective walkability were examined using partial Pearson correlations adjusted for sex and age. All analyses that included matched controls, except Pearson correlations, were implemented in SAS's GENMOD procedure using generalized estimating equations (GEE) with robust variance estimates to account for clustering between matched participants. The exchangeable working correlation was used for all models with continuous and binary outcomes, while the default working correlation (independence) was used for those with multinomial outcomes due to SAS constraints.

Multivariable linear regression models with adjustments for BMI, income, and current smoking were used to compare measures of active transportation, non-transportation PA, barriers to active transportation, and neighborhood walkability (including interaction model for perceived versus objective walkability) between adult CCS and controls. Adjusted means were evaluated at the mean levels of covariates included in the models. Each independent variable (except race/ethnicity, due to low cell numbers) was also entered into bivariate logistic regression models estimating the odds of engaging in active transportation (versus no active transportation). The active transportation variable was dichotomized because its distribution was highly right-skewed (i.e., a relatively large proportion of participants reported 0 hours/week). Variables with statistically significant odds ratios (ORs) in bivariate analyses were included in a multivariable logistic regression model. (Note: Using full models (include all independent variables, regardless of statistical significance in bivariate models) did not alter the results; the reduced models were chosen over the full models because they provided better model fit based on quasi-likelihood under the independence model criterion (QIC) values). All logistic regression analyses were performed separately for adult CCS and controls.

RESULTS

Adult CCS participants were more likely to be female (54.4% vs. 38.3%, $P=0.001$), non-Hispanic white (94.9% vs. 87.6%, $P=0.02$), and a leukemia survivor (35.4% vs. 23.7%, $P=0.01$) compared to non-participants. Control participants were more likely to be female (62.7% vs. 49.5%, $P=0.0002$) compared to non-participants. Walk Scores did not differ between participants and non-participants.

Characteristics of adult CCS and control participants are shown in Table 1. Controls were older, had higher household incomes, and were more likely to be female and a current smoker compared to adult CCS. BMI was marginally greater (26.5 vs. 25.2 kg/m², $P=0.06$)

in controls. There were no notable differences between adult CCS and controls in terms of race/ethnicity, education, the ratio of automobiles to drivers in the household, or the number of days required to go outside of the home for work, school, or volunteering.

Table 2 presents levels of active transportation and non-transportation PA, perceived barriers to active transportation, and perceived and objective neighborhood walkability scores. Based on multivariable linear regression models, adult CCS and controls reported similar levels of active transportation and non-transportation PA (leisure, work, and household) and had comparable perceptions of environmental, planning/psychosocial, and safety barriers to active transportation. Adult CCS scored significantly higher on the health barriers subscale (1.88 vs. 1.65, $P=0.01$), meaning they were more likely to indicate that their health (i.e., feeling too tired/fatigued and/or being limited by a physical or medical condition) made it difficult to walk or bike for transportation. Perceived and objective neighborhood walkability did not differ between adult CCS and controls. Furthermore, the correlation between perceived and objective walkability was similar for adult CCS and controls ($P_{\text{interaction}} = .42$).

Table 3 includes unadjusted and adjusted ORs for potential correlates of active transportation. In unadjusted bivariate logistic regression models, adult CCS who were older (OR = 0.91, 95% confidence interval (CI) = 0.86–0.95), had a higher BMI (OR = 0.94, 95% CI = 0.88–0.99), were married or living with a partner (OR = 0.27, 95% CI = 0.13–0.53), had access to more vehicles (OR = 0.13, 95% CI = 0.04–0.48), had been diagnosed less recently (OR = 0.93, 95% CI = 0.90–0.97), and perceived greater environmental (OR = 0.36, 95% CI = 0.20–0.65), planning/psychosocial (OR = 0.27, 95% CI = 0.14–0.53), and health (OR = 0.64, 95% CI = 0.43–0.95) barriers were less likely to engage in active transportation. Adult CCS who lived in a more walkable neighborhood (i.e., objective walkability) (OR = 1.02, 95% CI = 1.01–1.04) and perceived their neighborhood as more walkable (i.e., perceived walkability) (OR = 2.91, 95% CI = 1.76–4.83) were more likely to engage in active transportation. After combining all statistically significant correlates, with the exception of years since diagnosis (removed due to evidence of multicollinearity, VIF=2.9), into one adjusted multivariable logistic regression model, marital/relationship status (OR = 0.30, 95% CI = 0.11–0.81), planning/psychosocial barriers (OR = 0.15, 95% CI = 0.04–0.53), and perceived walkability (OR = 2.55, 95% CI = 1.14–5.66) remained significant correlates of active transportation in adult CCS. Among controls, those with a higher household income (>\$60,000–\$100,000 vs. \$20,000; OR = 3.60, 95% CI = 1.21–10.7) and greater perceived (OR = 1.73, 95% CI = 1.08–2.77) and objective (OR = 1.03, 95% CI = 1.01–1.05) walkability were more likely to engage in active transportation in unadjusted models. Objective walkability (OR = 1.03, 95% CI = 1.01–1.05) remained the only statistically significant correlate in the adjusted model.

DISCUSSION

Results from the TRACCS study suggest that adult CCS engage in similar levels of active transportation as controls despite facing greater health-related barriers. Adult CCS and controls also had comparable perceptions of neighborhood walkability and indicated they experienced very few environmental, planning/psychosocial, and safety-related barriers to

active transportation (i.e., mean scores were near 2; a score of 2 indicates participant “somewhat disagrees” that something is a barrier to their use of active transportation). Given the high prevalence of chronic health conditions in adult CCS, we expected health to be a greater barrier to active transportation in adult CCS than in controls. Although the difference in the health subscale between adult CCS and controls was statistically significant, it may be too small (0.23 on a 4-point Likert scale) to translate into appreciable differences in behavior. Moreover, the relatively low health subscale score of 1.88 indicates adult CCS likely encounter other factors that influence their transportation choices to a greater degree than their health. As the adjusted logistic regression model suggested, marital/relationship status, planning/psychosocial barriers, and perceived neighborhood walkability may have more influence on active transportation behaviors than health barriers among adult CCS. Among controls, living in a more walkable neighborhood (i.e., higher Walk Score) appeared to be the predominant indicator of active transportation behavior. While ORs for this measure were small, Walk Score is an ordinal variable from 0 to 100, so the ORs correspond to only a 1-unit increase in Walk Score.

Although no prior studies have examined active transportation in CCS nor compared active transportation between cancer survivors and controls, we are able to compare some of our findings with those from studies of adults from the general population. TRACCS participants and adults from previous studies that used the long, seven day recall version (rather than the past year usual week version used for TRACCS) of the IPAQ reported comparable levels of active transportation. In TRACCS, 62% of adult CCS and 64% of controls engaged in active transportation, with averages of 2.7 and 2.3 hours per week, respectively. Van Dyck et al. found approximately 68% of study participants from the Seattle and Baltimore regions engaged in any transport-related walking, with an average of 2.6 to 2.9 hours per week of combined walking and cycling for transportation [36]. These participants also engaged in similar levels of non-transportation PA (16.5 to 16.9 hours per week) as TRACCS participants (17.2 and 18.2 hours per week for controls and CCS, respectively). Hearst et al. noted an average of 2.6 hours per week of active transportation among participants from the Minneapolis/St Paul metropolitan area (non-transportation PA totals were not reported) [37]. Despite IPAQ modification and differences in study population and location, levels of active transportation and non-transportation PA were fairly comparable across studies.

Levels of active transportation in the U.S. have been shown to generally decrease with age, income, and vehicle access/availability and are lower among females [38]. Those with a graduate or professional degree and those who did not graduate from high school typically have the highest levels of active transportation. Non-Hispanic Whites tend to have the lowest levels of walking, while Blacks tend to have the lowest levels of bicycling [38]. There is limited or mixed evidence across studies for associations between active transportation and body weight, other physical activity, marital/relationship status, and smoking [15,39–41]. Although no other known studies have examined the actual number of days required to travel outside the home, there is evidence to suggest that individuals who work less than full time are more likely to use active transportation [15,42]. We saw comparable, albeit mostly non-significant, trends for age, vehicle access/availability, and sex in this study, along with similarly mixed results for BMI, other physical activity, marital/

relationship status, and smoking. Additional research is needed to confirm whether active transportation interventions should consider targeting certain “at-risk” demographic groups (e.g., older populations, females, and vehicle owners). Understanding the primarily non-modifiable influences on active transportation will be essential in the design of effective tailored interventions.

Individuals who perceive greater barriers to active transportation typically engage in less active transportation, as do those who live in less walkable neighborhoods (lower objective walkability) [43,44]. Greater access (perceived and objective) to destinations has been the most consistent individual environmental correlate of active transportation despite a fair amount of discordance between objective and perceived walkability [32,43,45–47]. Other environmental correlates such as street connectivity, aesthetics, and the presence of sidewalks have shown mixed results, along with measures of social support and safety [43]. To our knowledge, no studies have directly examined health-related barriers to active transportation, but some have shown that perceived health status, physical wellbeing, and/or reported number of chronic diseases are associated with active commuting to work [42,48–50]. Overall, there were mixed results for environmental, planning/psychosocial, safety, and health barriers in this study. Notably, higher Walk Scores have been associated with lower odds of not walking for transportation and with more minutes per week of walking for transportation [51]. Our results were consistent with this evidence, as higher Walk Scores were associated with active transportation in unadjusted models among adult CCS and controls and in fully adjusted models among controls. Self-selection, or personal preferences for residential neighborhoods based on travel preferences, may play a role in these observations, especially among relatively wealthy and highly educated study populations such as ours. Evidence from studies that have attempted to account for the effects of self-selection suggests the built environment remains a significant predictor of active transportation behavior after controlling for the partial explanation provided by self-selection [43]. Unfortunately, a measure of self-selection was not available in this study. Future studies should consider including measures of self-selection to help control for these factors.

We would have also liked to examine the presence of children in the household, since having children has been associated with lower levels of active transportation [38], but lacked a proper measure. Although the TRACCS survey ascertained the number of adults and children in the household, an unknown number of participants still lived at home with their parent(s) and/or sibling(s); thus we were unable to determine whether the children listed were underage siblings, dependents, or other relatives/non-relatives. Another limitation of this study was the use of questionnaire items for which reliability and/or validity measures are not available or may not be generalizable to our study population. Furthermore, non-transportation PA items may inherently capture parts of active transportation or vice versa, despite efforts to prevent this through explicit questionnaire instructions to not include transportation-related activities in the non-transportation sections and vice versa.

Relying on self-reported cross-sectional data created other limitations, including possible misclassification due to inaccurate recall of activities, non-responder bias, and the inability

to accurately assess changes in behaviors and perceptions over time. It would particularly be of interest to know how survivors' behaviors and perceptions have changed from before diagnosis to during and after treatment. Longitudinal studies may be warranted to explore potential changes and patterns, including changes that occur after age 45. If feasible, objective measures of active transportation such as pedometers, bike odometers, or GPS tracking, could be used in combination with self-report measures to improve accuracy. Divergent associations, albeit not statistically significant, across CCS and controls for education, household income, and the four barrier measures, as well as the change in direction of association from the unadjusted to adjusted models for environmental and health barriers (see Table 3) are notable but hard to interpret. Evidence of multicollinearity was weak, but there may have been enough correlation between certain variables to partially explain the changes in direction of association.

Despite its limitations, the TRACCS study had some important strengths. The use of matched neighborhood controls allowed for more efficient control of both known and unknown (i.e., neighborhood-level) covariates in the analysis and permitted us to check for spatial correlation in the data, of which there was none. Unlike most studies, ours was able to account for seasonal variations in behavior by asking participants to recall their usual patterns of travel during a typical week in the summer, winter, and fall/spring seasons. Lastly, using Walk Score, which uses the Google application programming interface to regularly update geographic data, helped avoid temporal problems that afflict GIS data sets [32].

In summary, our findings suggest that adult CCS and matched neighborhood controls have generally similar active transportation behaviors and perceptions. Although adult CCS consider their health to be a greater barrier to active transportation compared to controls, other factors appear to influence their behavior to a greater degree than their health. This evidence supports exploring the use of active transportation interventions in adult CCS to incorporate more PA into their daily lives. Such interventions are more likely to be effective if participants have access to highly walkable/bikeable neighborhoods. In contrast, success will be limited without existing or improved pedestrian and bicycle infrastructure, safety, and access to local amenities in all communities. Additional research is needed to confirm these results and investigate the feasibility and efficacy of active transportation interventions to change behavior and improve health in this population.

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Table 1

Characteristics of Adult CCS and Neighborhood Controls

		CCS (N=158)		Controls (N=153)		<i>P</i>
		N (%)	Mean ± SE	N (%)	Mean ± SE	
Sex						
Male		72 (45.6)		57 (37.3)		0.002
Female		86 (54.4)		96 (62.7)		
Age (years)			29.0 ± 0.6		30.9 ± 0.6	0.0001
Body Mass Index (kg/m²)			25.2 ± 0.5		26.5 ± 0.5	0.06
Race/Ethnicity						
White Non-Hispanic		150 (94.9)		139 (90.9)		0.54
Others		8 (5.1)		10 (6.5)		
Missing		--		4 (2.6)		
Married or living with a partner						0.001
No		92 (58.2)		64 (41.8)		
Yes		64 (40.5)		85 (55.6)		
Missing		2 (1.3)		4 (2.6)		
Education						0.70
High school graduate or GED		26 (16.5)		19 (12.4)		
Some college		43 (27.2)		46 (30.1)		
College graduate or more		87 (55.1)		84 (54.9)		
Missing		2 (1.3)		4 (2.6)		
Household Income						0.001
\$20,000		28 (17.7)		17 (11.1)		
>\$20,000–\$40,000		24 (15.2)		16 (10.5)		
>\$40,000–\$60,000		32 (20.3)		21 (13.7)		
>\$60,000–\$100,000		34 (21.5)		52 (34.0)		

	CCS (N=158)		Controls (N=153)		P
	N (%)	Mean ± SE	N (%)	Mean ± SE	
>\$100,000	28 (17.7)		41 (26.8)		
Missing	12 (7.6)		6 (3.9)		
Household Motor Vehicles (vehicles/driver)					0.18
<1 vehicle per driver	23 (14.6)		15 (9.8)		
1 vehicle per driver	133 (84.2)		138 (90.2)		
Missing	2 (1.3)		--		
Days Required to Go Outside Home for Work/School/ Volunteering					0.88
0–2 days per week	24 (15.2)		15 (9.8)		
3–4 days per week	22 (13.9)		19 (12.4)		
5 days per week	64 (40.5)		84 (54.9)		
6–7 days per week	46 (29.1)		31 (20.3)		
Missing	2 (1.3)		4 (2.6)		
Current Smoker					0.03
No	147 (93.0)		131 (85.6)		
Yes	11 (7.0)		22 (14.4)		
Diagnosis					
Leukemia (ALL, AML)	56 (35.4)		NA		
Lymphoma (HOD, NHL)	31 (19.6)				
Osteosarcoma	19 (12.0)				
Central nervous system	16 (10.1)				
Others	36 (22.8)				
Years since Diagnosis					
		18.4 ± 0.7		NA	

Abbreviations: CCS, childhood cancer survivors; NA, not applicable; SE, standard error.

Table 2

Self-Reported Active Transportation and Non-transportation Physical Activity, Perceived Barriers to Active Transportation, and Perceived and Objective Neighborhood Walkability in Adult CCS and Neighborhood Controls

	CCS (N=158)			Controls (N=153)		
	Mean ± SE ^a	N (%)		Mean ± SE ^a	N (%)	<i>P</i> ^a
Active Transportation (hours/week)						
No Active Transportation	2.72 ± 0.49	56 (35.4)		2.32 ± 0.50	53 (34.6)	0.40
Some Active Transportation		98 (62.0)			98 (64.1)	0.39
Missing		4 (2.5)			2 (1.3)	
Non-transportation PA (hours/week)	18.2 ± 1.6			17.2 ± 1.7		0.52
Barriers to Active Transportation^b						
Environment	2.04 ± 0.07			2.07 ± 0.07		0.70
Planning/Psychosocial	1.96 ± 0.07			2.02 ± 0.06		0.42
Safety	1.41 ± 0.06			1.41 ± 0.07		0.90
Health	1.88 ± 0.08			1.65 ± 0.07		0.01
Neighborhood Walkability						
Perceived ^c	2.13 ± 0.10			2.24 ± 0.11		0.21
Objective (Walk Score) ^d	29.3 ± 2.5	123 (77.9)		30.4 ± 2.6	118 (77.1)	0.39
Car-Dependent (0–49)		25 (15.8)			23 (15.0)	
Somewhat Walkable (50–70)		10 (6.3)			12 (7.8)	
Very Walkable (70–100)						
Perceived Walkability versus Objective Walkability	0.62	<.0001		0.65	<.0001	0.42

Abbreviations: CCS, childhood cancer survivors; PA, physical activity; SE, standard error.

^a Adjusted for body mass index, income, smoking, and clustering of matched participants (matched on sex, age, and location).

^b Measured on four-point Likert scales, where 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, and 4=strongly agree that a particular barrier makes it difficult to actively travel.

^c Scores range from 1 to 5, with higher scores indicating greater perceived walkability.

^d Walk Scores range from 0 to 100, with higher scores indicating greater walkability.

^e Adjusted for sex and age.

Table 3

Odds of Engaging in Active Transportation among Adult CCS and Neighborhood Controls

	CCS (N=144)		Controls (N=140)	
	Unadjusted OR (95% CI)	Adjusted ^a OR (95% CI)	Unadjusted ^b OR (95% CI)	Adjusted ^{a,b} OR (95% CI)
Sex (ref = male)	0.62 (0.31–1.21)	--	0.70 (0.34–1.46)	--
Age (years)	0.91 (0.86–0.95)	0.95 (0.88–1.02)	0.96 (0.91–1.01)	--
Body Mass Index (kg/m²)	0.94 (0.88–0.99)	0.93 (0.85–1.02)	0.99 (0.95–1.04)	--
Education				
High school graduate or GED (ref)	1.00	--	1.00	--
Some college	1.85 (0.67–5.09)	--	0.65 (0.16–2.62)	--
College graduate or more	1.69 (0.69–4.17)	--	0.97 (0.26–3.60)	--
Household Income				
\$20,000 (ref)	1.00	--	1.00	1.00
>\$20,000–\$40,000	0.69 (0.20–2.46)	--	1.65 (0.49–5.60)	2.20 (0.56–8.60)
>\$40,000–\$60,000	0.33 (0.10–1.04)	--	1.43 (0.38–5.41)	1.29 (0.31–5.39)
>\$60,000–\$100,000	0.39 (0.12–1.21)	--	3.60 (1.21–10.7)	3.25 (0.98–10.8)
>\$100,000	0.33 (0.10–1.07)	--	1.04 (0.38–2.84)	1.13 (0.35–3.68)
Married or living with a partner (ref = no)	0.27 (0.13–0.53)	0.30 (0.11–0.81)	0.60 (0.32–1.13)	--
Vehicles per driver	0.13 (0.04–0.48)	0.14 (0.01–1.33)	0.33 (0.11–1.01)	--
Days Required to Go Outside Home for Work/School/Volunteering				
0–2 days per week (ref)	1.00	--	1.00	--
3–4 days per week	1.05 (0.32–3.48)	--	0.57 (0.16–2.05)	--
5 days per week	0.78 (0.30–2.05)	--	0.92 (0.29–2.89)	--
6–7 days per week	1.60 (0.55–4.62)	--	0.75 (0.21–2.67)	--
Current Smoker (ref = no)	0.30 (0.08–1.07)	--	1.70 (0.62–4.62)	--
Diagnosis				
Leukemia (ALL, AML) (ref)	1.00	--		
Lymphoma (HOD, NHL)	0.67 (0.27–1.68)	--	NA	NA
Osteosarcoma	0.93 (0.31–2.76)	--		
Central nervous system	0.54 (0.18–1.68)	--		
Others	1.63 (0.64–4.16)	--		
Years since Diagnosis	0.93 (0.90–0.97)	--	NA	NA
Leisure/work/household PA (hours/week)	1.01 (0.99–1.04)	--	1.02 (0.99–1.04)	--
Environmental Barriers^c	0.36 (0.20–0.65)	1.61 (0.59–4.43)	1.27 (0.71–2.29)	--

	CCS (N=144)		Controls (N=140)	
	Unadjusted OR (95% CI)	Adjusted ^a OR (95% CI)	Unadjusted ^b OR (95% CI)	Adjusted ^{a,b} OR (95% CI)
Planning/Psychosocial Barriers^c	0.27 (0.14–0.53)	0.15 (0.04–0.53)	1.22 (0.73–2.06)	--
Safety Barriers^c	0.67 (0.34–1.34)	--	2.01 (0.80–5.07)	--
Health Barriers^c	0.64 (0.43–0.95)	1.15 (0.61–2.16)	1.05 (0.70–1.58)	--
Perceived Walkability^d	2.91 (1.76–4.83)	2.55 (1.14–5.66)	1.73 (1.08–2.77)	0.97 (0.51–1.86)
Objective Walkability^e	1.02 (1.01–1.04)	1.01 (0.98–1.03)	1.03 (1.01–1.05)	1.03 (1.01–1.05)

Abbreviations: CCS, childhood cancer survivors; CI, confidence interval; NA, not applicable; OR, odds ratio. Bolded ORs and 95% CIs indicate statistical significance ($P < .05$).

^a Adjusted for variables that were significantly related to the dependent variable in unadjusted analyses.

^b Adjusted for clustering of matched controls (matched on sex, age, and location).

^c Measured on four-point Likert scales, where 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, and 4=strongly agree that a particular barrier makes it difficult to actively travel.

^d Scores range from 1 to 5, with higher scores indicating greater perceived walkability.

^e Walk Scores range from 0 to 100, with higher scores indicating greater walkability.

^f Removed from adjusted model due to multicollinearity (variance inflation factor = 2.9)