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Health Behavior Profiles in Young Survivors of Childhood Cancer: Findings from the St. Jude Lifetime Cohort Study (SJLIFE)

Rachel Tillery Webster, PhD[1,2], **Rikeenkumar Dhaduk, MPH**[2], **Mallorie L. Gordon, PhD**[1], **Robyn E. Partin, MS**[3], **Alicia S. Kunin-Batson, PhD**[5], **Tara M. Brinkman, PhD**[1,2,3], **Victoria W. Willard, PhD**[1,2], **Jennifer M. Allen, PhD**[1], **Nicole M. Alberts, PhD**[6], **Jennifer Q. Lanctot, PhD**[3], **Matthew J. Ehrhardt, MD**[2,3,4], **Zhenghong Li, MS**[3], **Melissa M. Hudson, MD**[1,2,3,4], **Leslie L. Robison, PhD**[2,3,4], **Kirsten K. Ness, PT, PhD**[2,3]

[1]Psychology, St. Jude Children's Research Hospital, Memphis, TN

[2]Comprehensive Cancer Center, St. Jude Children's Research Hospital, Memphis, TN

[3]Epidemiology and Cancer Control, St. Jude Children's Research Hospital, Memphis, TN

[4]Oncology, St. Jude Children's Research Hospital, Memphis, TN

[5]Pediatrics, University of Minnesota Medical School, Minneapolis, MN

[6]Psychology, Concordia University, Montreal, Quebec

Abstract

Background: There is limited understanding of associations between a combination of health behaviors (physical activity, sedentary/screen-time, diet) and cardiometabolic health risk factors, physical performance, and emotional health among young (<18) childhood cancer survivors (CCS). The aims of this research were to address this gap by: (1) deriving health behavior adherence profiles among CCS, and (2) examining associations among demographic, diagnosis/ treatment exposures , cardiometabolic, physical performance, and emotional functioning with health behavior profile membership.

Methods: Participants included 397 CCS (≥ 5 years post-diagnosis; aged 10-17) enrolled in the St. Jude Lifetime Cohort Study who completed physical health evaluations and questionnaires assessing health behaviors and psychological functioning. Latent profile analysis was used to derive profiles of health behavior adherence. Logistic regression and t-tests were used to examine mean-level differences and associations between profile membership with demographic, diagnosis, treatment exposures, cardiometabolic health, psychological functioning, and physical performance.

Corresponding Author: Rachel Tillery Webster, PhD, St. Jude Children's Research Hospital, Department of Psychology, 262 Danny Thomas Place, MS 740, Memphis, TN 38105, 901.595.7946, Rachel.Webster@stjude.org.

Author Contributions: Drs. Webster, Gordon, and Ness conceptualized drafted, reviewed, and revised the manuscript. Ms. Partin and Dr. Lanctot designed data collection instruments/approach, supervised data collection, and reviewed/ revised manuscript. Mr. Dhaduk and Mr. Li conducted data analyses. Drs. Kunin-Batson, Brinkman, Willard, Allen, Alberts, and Ehrhardt edited the manuscript and reviewed scientific content. Drs. Hudson, Ness, and Robison conceptualized and designed the study, coordinated, and supervised study teams carrying out this research, and critically reviewed and edited the manuscript's scientific content.

Conflicts of Interest: The authors declare no conflicts of interest.

Results: Two profiles emerged: inactive-unhealthy-diet (“IU”) and active-sedentary-unhealthy-diet (“ASU”) to guidelines. More participants in IU demonstrated higher resting heart rate (*mean [M]*=76.54, *standard deviation [SD]* =12.00) and lower motor proficiency scores (*M*=34.73, *SD* =29.15) compared to ASU (resting heart rate, *M*=71.95, *SD* =10.74; motor proficiency, *M*=50.40, *SD* =31.02).

Conclusion: CCS exhibited low adherence to multiple health behavior guidelines, with adherence patterns differentially associated with cardiometabolic health (i.e., resting heart rate) and physical performance. However, robust protection against all health variables was not observed. Findings suggest interventions designed to improve health outcomes should target multiple health behaviors simultaneously.

Plain Language Summary:

Pediatric cancer survivors are at-risk for detrimental health outcomes associated with cancer and treatment. Engagement in healthy lifestyle behaviors serves to reduce health vulnerabilities among adult survivors, but less is known about associations with lifestyle behaviors on young survivors. This study documents patterns of lifestyle behaviors among survivors of pediatric cancer, factors that increase susceptibility to nonadherence, and associations among lifestyle behaviors and health indicators.

Precis:

Young (<18 years of age) survivors of pediatric cancer exhibit poor adherence to diet and physical activity guidelines. Adherence associated with clinical health outcomes.

Keywords

child and adolescent survivors; physical activity; diet; cardiometabolic risk; mobility

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Childhood cancer survivors (CCS) are at increased risk of poor health outcomes secondary to treatment and disease-related factors, including poor cardiometabolic, physical, and emotional health.[1] Engagement in healthy lifestyle behaviors (HLB; i.e., exercise, healthful diet, limited sedentary/screen-time behavior) substantially reduces risk of adverse cancer-related sequelae and improves health functioning in adult CCS.[2-4] While many studies have examined links between HLBs and health outcomes in adult CCS, research devoted to this relationship in young CCS (i.e., <18 years of age) is sparse.[5]

Findings in younger CCS populations consistently indicate CCS are not meeting behavioral guidelines across multiple health domains,[6] but little is understand about the associations among HLBs and how patterns relate to cardiometabolic, physical, and emotional health. A recent review of HLB among youth without chronic illnesses found HLBs typically cluster into combinations of healthy and unhealthy behaviors (i.e., high physical activity and high sedentary behavior), and the combination of these behaviors differentially predicted health outcomes.[7] Thus, it is not sufficient to examine a single health behavior in isolation, as patterns of engagement may differentially predict health outcomes in young CCS.

There is a critical need to identify young CCS at-risk for poor health habits and how the combination of HLBs impact cardiometabolic, physical, and emotional health. As such our aims for this investigation were: (1) to empirically derive health behavior profiles of young CCS (10-17 years of age), and (2) to determine which demographic, cancer-related medical factors (i.e., diagnosis, treatment exposures), cardiometabolic risk (i.e., blood pressure, body mass index, body fat percentage), emotional functioning (i.e., depression, anxiety, pain interference),and physical performance (i.e., motor proficiency, physiological cost, physical activity exertion, average respiration) factors were associated with health behavior (i.e., physical activity, strength training, sedentary behavior, screen time, diet) profile membership. Based on prior research, we hypothesize demographic and medical characteristics such as female sex, lower socioeconomic status, and history of cranial radiation will be associated with profiles characterized by decreased physical activity.[6,8,9] Younger age at diagnosis, lower socioeconomic status, and abdominal radiation will be associated with profiles characterized by poor dietary behaviors.[6,10] Mental health difficulties[8,11] and experiences of pain[12] will be associated with profiles characterized by poor diet and low physical activity levels.

Methods

Study Population and Procedures.

Participants included members of the St. Jude Lifetime Cohort Study (SJLIFE), a retrospective cohort with longitudinal follow-up and ongoing enrollment, which was designed to examine health outcomes among CCS. Surveys and self-reported data were collected by trained study coordinators. Cardiometabolic and physiological data were collected by trained study staff including exercise physiologists and physical therapists. Comprehensive details related to study methodology and characteristics have been described elsewhere.[13] Participants included in these analyses were between 10-17.99 years of age with a history of pediatric cancer and >5 years post diagnosis at the time of the assessment. Details pertaining to demographic, diagnosis, and treatment exposures are presented in Table 1. Legal guardians provided consent and patients provided assent for participation. All procedures were approved by the institutional IRB.

Measures

Demographic and Medical History.—Participants' medical diagnosis, birth date, and diagnosis date, and treatment exposures were collected through medical records. Caregivers self-reported income and race/ethnicity. Chronic health conditions were categorized as present (CTCAE grades 2-4) or not present (no diagnosed chronic health condition or CTCAE grade 1)[14]

Health Behaviors.—Physical activity, screen time, and sedentary behaviors were assessed using items from the National Health and Nutrition Examination Survey[15] via adolescent self-report. Items included physical activity (i.e., number of days physically active for 60 or minutes within a week, number of days strength training or toning muscles), sedentary time (i.e., number of hours of sedentary time per day), screen time (i.e., number of hours viewing television, number of hours of playing video games per day). Higher scores indicate more time spent within that behavior. Dietary behaviors were measured using the well-established Block Kids Food Frequency Questionnaire via adolescent self-report.[16-18]An overall Healthy Eating Index (HEI) score, which is a summary indicator of participant conformance to the Dietary Guidelines for Americans, was assigned. The HEI ranges from 0 to 100 with higher scores indicating better diet quality. The average score for the United States population of 59.[19]

Cardiometabolic Health Risk Indicators.—*Resting heart rate (HR) and blood pressure* were assessed following a 5-minute resting period, in which participants were in a seated position with feet flat on the floor. Readings were manually measured in duplicate, with five minutes between readings and the lowest value was recorded. Blood pressure levels were considered elevated when all three readings for systolic blood pressure (SBP) ≥ 120 and all three readings of diastolic blood pressure (DBP) ≥ 80 were elevated.[20]

***Body mass index* (BMI)** was calculated as weight in kilograms divided by height in meters squared. Sex and age-adjusted standardized BMI scores were calculated using the 2000 Centers for Disease Control (CDC) growth chart.[21]

Body fat percentage was assessed via skinfolds following established guidelines.[22] The average of two skinfolds were measured at the triceps and subscapular skinfolds for both males and females, and the sum of the two averaged skinfolds were imputed to the appropriate prediction equation based on sex, race, and maturation.[23] Sex and age-specific thresholds were used to create cut scores for elevated body fat.[24]

Physical Performance Indicators.—R*espiration rate* was assessed following a 5-minute resting period, while participants were seated. Readings were manually measured in duplicate, with five minutes between readings and the lowest value was recorded.

Motor proficiency was assessed using the Bruininks-Oseretsky Test of Motor Proficiency Short Form 2nd Edition (BOT-2).[25] An overall mobility score was derived: fine motor precision, fine motor integration, manual dexteriy, bilateral coordination, balance, running speed and agility, upper-limb coordination, and strength. Raw scores were converted into a standard score based on sex, age, and the type of push-up performed in the strength section (knee or full push-up).[26] The standard score has a mean of 50 and a standard deviation of 10, and participants were classified as well-above average (standard score ≥70), above average (standard score 60-69), average (standard score 41-59), below average (standard score 31-40), or well-below average (standard score ≤30).[26]

Physiological cost index (PCI) was assessed using the six minute walk test (6MW). PCI is a valid and reliable method to measure the energy cost of walking in healthy and diseased populations.[27-30] A resting heart rate (HR) and Borg rating of perceived exertion (RPE)[31] were documented after participants rested for 5 minutes prior to the start of the 6MW. Participants were instructed to walk as quickly as possible, without running, for the entire 6 minutes on a predetermined 40 meter course. HR and RPE were documented at the 2, 4, and 6 minute time points.[32] PCI was calculated as maximal working HR minus resting HR divided by walking speed (total distance walked in meters per minute), and a lower score indicates better energy efficiency.

Emotional Functioning Indicators.—*Pain* was assessed using the 8-item Patient-Reported Outcomes Measures Information System (PROMIS) Pain Interference-Short Form v 2.0 was used to evaluate self-reported consequences of pain. ***Anxiety*** was assessed using the PROMIS 8-item Pediatric Anxiety-Short Form version 2.0. ***Depression*** was assessed using the PROMIS 8-item Pediatric Depressive Symptoms-Short Form version 2.0. Each measure included response items on a 5-point scale ranging from "never" to "almost always". Total scores are converted to T scores with a mean of 50 and standard deviation of 10. Higher scores indicate worse functioning. Each measures has excellent psychometric properties.[33,34]

Statistical Analyses.

Latent profiles analysis was conducted to empirically derive health behavior profiles of young CCS using physical activity, sedentary behavior, and dietary intake. The Bayesian information criterion (BIC)[35] was used to determine model fit for each number of classes estimated, with lower BIC values indicating better model fit.[36] The Vuong-Lo-Mendell-Rubin (VLRM)[37,38] was used to compare model improvement between neighboring classes solutions (e.g., 2 class solution vs. 3 class solution, 3 vs. 4). A significant *p*-value (<.05) derived from these tests indicates statistically significant improvement in fit by the addition of a class.[36] Entropy values were used to assess model classification, with values above 0.75 considered ideal.[39] To compare mean-level differences in cardiometabolic risk, physical performance, and emotional functioning across latent profiles, a series of t-tests were performed. To determine associations between demographic, diagnosis/treatment exposures, cardiometabolic risk, physical performance, and emotional functioning logistic regressions were performed. Regressions were performed separately for diagnosis and treatment exposures. All analyses were performed using SAS/STAT version 9.4 software of the SAS System for Windows (Cary, NC, USA).

Results

Participants.

Of 635 eligible, consented participants, 445 (70%) completed an on-site comprehensive health evaluation (Supplemental Figure 1). The majority of participants were female (52%) and non-Hispanic White (69%), with a history of hematologic, neurologic, and solid tumor diagnoses, and ranged in age from 0-10 years at cancer diagnosis (Table 1). Participants and non-participants (i.e., those who did not yet complete onsite visits) did not differ by sex (X^2 [df=1]=2.18, p=.14), race/ethnicity (X^2 [df=3]=3.87, p=.28), age at assessment t(431) =-0.82, p=.41)., or family income (X^2 [df=5]=4.44, p=.60). Non-participants varied in diagnostic category (p=.03) and were slightly older at age of diagnosis (Mean [M]=4.48, SD =2.56) as compared to participants (M=3.34, SD =2.40; t(479) =2.72, p<.01).

Latent Profiles.

Complete data were available for 397 participants. Those with missing data were excluded from latent profile analyses. Latent profile analyses indicated a 4-class solution provided the best BIC value (Supplemental Table 1); however, this solution provided a non-significant VLMR and a class size too small (5%) to be considered meaningful. The 2 and 3-class solution provided the next optimal BIC values. Based on model fit indices, the 2-class solution was chosen over the 3-class solution as the BIC value change was not robust, and the entropy for the 3-class model was low. Finally, we explored if the 4-class and 2-class models were qualitatively different. Based on mean differences across the profiles, the addition of 2 profiles did not meaningfully change the characterization of the population. Thus, we chose the more parsimonious model (see Supplemental Table 2).

The majority of participants (75%) were characterized as "inactive-unhealthy-diet" group ("IU") with an average of ~3 days of 60 minutes of physical activity, <1 day of strength training per week, >7 daily hours of sitting time, > 6 daily hours of screen time, and an overall HEI score of 53.59 (Table 2). The remaining participants comprised a group characterized as "active-sedentary-unhealthy-diet" to health guidelines ("ASU"). This group exhibited a combination of higher physical activity, as they self-reported an average of 5 days of 60 minutes of physical activity and ~5 days of strength training per week. However, participants in the ASU group also exhibited high sedentary behaviors including 6.5 daily hours of sitting time and > 6 daily hours of screen time. In addition overall HEI dietary scores were 53.59, falling below recommended guidelines (Table 2).

Mean Differences in Cardiometabolic Risk Factors, Physical Performance, and Psychological Health.

More participants had elevated body fat (26%) in the IU group compared to the ASU group (19%), though overall mean-level differences in body fat percentage were not statistically significant across profiles. The IU group also demonstrated significantly higher resting heart rate values than the ASU and lower motor proficiency scores (Table 3).

Multiple Variable Models.

Across the two multiple variable models examining demographic, diagnosis or treatment exposure-related variables, cardiometabolic risk indicators, physical performance indicators, and emotional health indicators, only motor proficiency emerged as a significant indicator of profile membership with higher motor proficiency scores increasing the odds of belonging to the ASU as compared to the IU profile (OR=1.01, CI: 1.00-1.02, p=.02; Supplemental Tables 3 and 4). Given non-significant associations with demographic, diagnosis, and treatment variables, a third model was performed with those variables removed. In this model (Table 4), average resting rate (OR=0.97, CI: 0.95-1.00, p=.05) and physical activity exertion (OR=0.91, CI: 0.84-0.99, p=.04) decreased the odds of belonging to the ASU as compared to the IU profile, whereas motor proficiency (OR=1.01, CI: 1.00-1.02, p=.01) increased the odds of belonging to the ASU profile.

Discussion

To reduce morbidity and mortality associated with cancer and cancer treatment, CCS are encouraged to exercise regularly, eat a healthful diet, and limit sedentary behavior. Though previous research has documented limited uptake of HLBs among young CCS,[8] these behaviors were often considered in isolation with limited understanding of the impact of poor HLB engagement on health comorbidities. The present research examined patterns of multiple HLBs and the implications of HLBs among young CCS.

Consistent with prior literature, that documented a combination of healthful and unhealthful behaviors in non-cancer youth,[40,41] our findings highlight a significant proportion of young CCS exhibit a combination of healthful and unhealthful behavior patterns. That is, for a subset of adolescents engaging in higher than average physical activity behaviors, they also reported elevated sedentary behavior and unhealthy dietary behaviors. Though one profile (ASU) emerged as on-average more active, no profile pattern emerged that demonstrated adherence to any health behavior guideline. These findings suggest all young CCS would benefit from regular and routine guidance to optimize lifestyle behaviors, and that screenings and interventions should be designed to target multiple HLBs.

Research among adult CCS found associations between poor health behavior uptake and risks for long-term health outcomes. Indeed, findings from this research indicate that decreased physical activity, poor dietary habits, and high sedentary behavior were associated with higher resting heart rate and worse physical performance. Thus, focusing on HLBs in early survivorship through increasing physical activity, reducing sedentary behavior/screen time, and improving healthful dietary uptake is critical for mitigating, concurrent difficulties with cardiometabolic and physical performance health and the risks to long-term health outcomes.

Across all models, motor proficiency was higher within the ASU group as compared to the IU group, whose mean score fell within the low average range. Given the cross-sectional design of this research, it is impossible to determine the directionality of this finding. Certainly, increasing physical activity can improve motor proficiency;[42] however decreased motor proficiency after treatment may be associated with decreased physical activity.[43] In either scenario, regular, ongoing assessment of motor proficiency and rehabilitative interventions are necessary for the significant subset of young CCS with poor motor proficiency.

A number of cardiometabolic risk (i.e., blood pressure, body mass index, body fat), physical performance (i.e., activity exertion, physiological cost, average respirations), and emotional health (i.e., depression, pain, anxiety) indicators did not differentiate between profiles as hypothesized. There may be several contributing factors. First, it is possible these factors are not associated with adherence to HLB guidelines. Given the robust literature documenting otherwise,[6,8-12] this is an unlikely explanation. An alternative possibility is that physical activity alone, without adherence to sedentary and dietary guidelines, was insufficient for protecting against certain cardiometabolic, physical performance, and emotional health indicators. Indeed, research supports links between sedentary and dietary behaviors with cardiometabolic risk, physical performance, and emotional functioning.[6,44,45] Finally, some variables were elevated across both profiles and that may be more likely due to the cancer experience than adherence to HLBs alone. For example, though pain interference scores (IU, T=43.692; ASU, T=45.17), were slightly elevated as compared to normative levels (i.e., T=36),[46] pain was not associated with profile membership in the present study. Restricted variability due to elevated pain scores across the current samples compared to national norms suggests may explain why adherence to guidelines is low across the entire sample. This is consistent with prior research.[12]

Prior research has indicated medical diagnoses and comorbidities associated with treatment exposures (e.g., radiation) were linked to engagement in healthful lifestyle behaviors;[6,9] however these factors were not associated in this study. In addition, prior research has documented marginalized youth from lower income families were more susceptible to poor health behavior engagement,[6,10] but again, this did not appear to drive associations within this study. Though these findings were not consistent with our hypotheses, research exploring HLBs among CCS in early survivorship have documented similar findings.[47] Non-significant findings may be related to younger age of this sample, and indicate other factors not included in the present study (e.g., parenting behaviors) may explain HLB adherence within this unique population. Alternatively, given poor adherence across both profiles, limited variability may have concealed these associations.

Though these findings are novel, and a major strength of this research includes objective assessments of physical performance and cardiometabolic risk indicators, findings should be considered in-light of several limitations. First, the cross-sectional, correlational design limits implications that can be drawn from this research. Examining these associations over time and within randomized clinical trials will be important for future research. Second, HLBs were only assessed via child/adolescent self-report, who historically underreport poor dietary intake[48] and moderate congruency with physical activity.[49] However, even with potential for inflation of self-reported engagement in HLBs, adolescents across both profiles, on average, failed to meet guidelines. Third, physical activity assessments did not consider the intensity (i.e., moderate-vigorous) of physical activity adolescents were engaging in, so it is possible findings indicate greater nonadherence than was found in the present study. Fourth, caregivers are critical to the uptake of adolescent HLBs,[50] but caregiver factors were not considered in this study. This will be imperative in future research, particularly for intervention development. Finally, the majority of the sample identified as non-Hispanic White and non-Hispanic Black, and it isunclear how these findings might translate to other populations in the US, and therefore should be interpreted with caution.

Our findings highlight that young CCS fall short of established health behavior guidelines in multiple domains. Even among survivors who were more physically active, physical activity alone was not sufficient to offset the risk of poor dietary behaviors and elevated sedentary behaviors. Taken together, all young CCS should receive routine assessment of HLBs across multiple health behavior domains. Interventions designed to improve health behavior uptake among young CCS should target multiple HLBs as adherence to one health behavior may not offer robust protection against multiple indicators of health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Hudson MM, Ness KK, Gurney JG, et al. Clinical ascertainment of health outcomes among adults treated for childhood cancer. JAMA. 2013;309(22):2371–2381. [PubMed: 23757085]
2. Doyle C, Kushi LH, Byers T, et al. Nutrition and physical activity during and after cancer treatment: an American Cancer Society guide for informed choices. CA Cancer J. Clin 2006;56(6):323–353. [PubMed: 17135691]
3. Smith WA, Li C, Nottage KA, et al. Lifestyle and metabolic syndrome in adult survivors of childhood cancer: a report from the St. Jude Lifetime Cohort Study. Cancer. 2014;120(17):2742–2750. [PubMed: 25070001]
4. Zhang FF, Hudson MM, Huang IC, et al. Lifestyle Factors and Health-Related Quality of Life in Adult Survivors of Childhood Cancer: A Report From the St. Jude Lifetime Cohort Study. Cancer. 2018.
5. Carretier J, Boyle H, Duval S, et al. A review of health behaviors in childhood and adolescent cancer survivors: toward prevention of second primary cancer. J. Adolesc. Young Adult Oncol 2016;5(2):78–90. [PubMed: 26812458]
6. Stolley MR, Restrepo J, Sharp LK. Diet and physical activity in childhood cancer survivors: a review of the literature. Ann. Behav. Med 2010;39(3):232–249. [PubMed: 20559768]
7. Leech RM, McNaughton SA, Timperio A. The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. International Journal of Behavioral Nutrition and Physical Activity. 2014;11(1):4. [PubMed: 24450617]
8. Devine KA, Mertens AC, Whitton JA, et al. Factors associated with physical activity among adolescent and young adult survivors of early childhood cancer: A report from the childhood cancer survivor study (CCSS). Psycho-oncology. 2018;27(2):613–619. [PubMed: 28805953]
9. Ness KK, Leisenring WM, Huang S, et al. Predictors of inactive lifestyle among adult survivors of childhood cancer. Cancer. 2009;115(9):1984–1994. [PubMed: 19224548]
10. Zhang FF, Ojha RP, Krull KR, et al. Adult Survivors of Childhood Cancer Have Poor Adherence to Dietary Guidelines–4. The Journal of nutrition. 2016;146(12):2497–2505. [PubMed: 27798341]
11. Klosky JL, Howell CR, Li Z, et al. Risky health behavior among adolescents in the childhood cancer survivor study cohort. J. Pediatr. Psychol 2012;37(6):634–646. [PubMed: 22427699]
12. Cox CL, Montgomery M, Oeffinger KC, et al. Promoting physical activity in childhood cancer survivors: results from the Childhood Cancer Survivor Study. Cancer. 2009;115(3):642–654. [PubMed: 19117349]
13. Howell CR, Bjornard KL, Ness KK, et al. Cohort profile: the St. Jude Lifetime Cohort Study (SJLIFE) for paediatric cancer survivors. Int. J. Epidemiol 2021;50(1):39–49. [PubMed: 33374007]
14. Hudson MM, Ehrhardt MJ, Bhakta N, et al. Approach for Classification and Severity Grading of Long-term and Late-Onset Health Events among Childhood Cancer Survivors in the St. Jude Lifetime CohortSeverity Grading of Late Effects in Cancer Survivors. Cancer Epidemiology, Biomarkers & Prevention. 2017;26(5):666–674.
15. US Department of Health and Human Services : National Health and Nutrition Examination Survey. 2007-2008 Data Documentation C, and Frequencies. Physical Activity (PAQ_E) 2009 https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/PAQ_E.htm#Component_Description.

16. Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. American journal of epidemiology. 1986;124(3):453–469. [PubMed: 3740045]

17. Block G, Murphy M, Roullet J, Wakimoto P, Crawford P, Block T. Pilot validation of a FFQ for children 8–10 years. Paper presented at: Fourth International Conference on Dietary Assessment Methods2000.

18. Cullen KW, Watson K, Zakeri I. Relative reliability and validity of the Block Kids Questionnaire among youth aged 10 to 17 years. J. Am. Diet. Assoc 2008;108(5):862–866. [PubMed: 18442512]

19. Krebs-Smith SM, Pannucci TE, Subar AF, et al. Update of the healthy eating index: HEI-2015. Journal of the Academy of Nutrition and Dietetics. 2018;118(9):1591–1602. [PubMed: 30146071]

20. Flynn JT, Kaelber DC, Baker-Smith CM, et al. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. Pediatrics. 2017;140(3).

21. Kuczmarski RJ. CDC growth charts: United States. US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statsitics: 2000.

22. Pescatello LS AR, Riebe D, Thompson PD. ACSM's guidelines for exercise testing and prescription. 9th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2014.

23. Slaughter MH, Lohman TG, Boileau RA, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol. 1988;60(5):709–723. [PubMed: 3224965]

24. Laurson KR, Eisenmann JC, Welk GJ. Development of youth percent body fat standards using receiver operating characteristic curves. American Journal of Preventive Medicine. 2011;41(4):S93–S99. [PubMed: 21961618]

25. Jirovec J, Musalek M, Mess F. Test of Motor Proficiency Second Edition (BOT-2): Compatibility of the Complete and Short Form and Its Usefulness for Middle-Age School Children. Front Pediatr. 2019;7:153. [PubMed: 31065548]

26. Bruininks RH MB, BD. Bruininks-Oseretsky Test of Motor Proficiency: Manual. Bloomington, MN: PsychCorp; 2005.

27. Bailey MJ RC. Reliability of physiological cost index measurements in walking normal subjects using steady-state, non-steady-state and post-exercise heart rate recording. Physiotherapy. 1995;81(10):618–623.

28. Fredrickson E, Ruff RL, Daly JJ. Physiological Cost Index as a proxy measure for the oxygen cost of gait in stroke patients. Neurorehabil Neural Repair. 2007;21(5):429–434. [PubMed: 17409390]

29. Graham RC, Smith NM, White CM. The reliability and validity of the physiological cost index in healthy subjects while walking on 2 different tracks. Arch Phys Med Rehabil. 2005;86(10):2041–2046. [PubMed: 16213251]

30. Ijzerman MJ, Nene AV. Feasibility of the physiological cost index as an outcome measure for the assessment of energy expenditure during walking. Arch Phys Med Rehabil. 2002;83(12):1777–1782. [PubMed: 12474186]

31. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377–381. [PubMed: 7154893]

32. Holland AE, Spruit MA, Troosters T, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. Eur Respir J. 2014;44(6):1428–1446. [PubMed: 25359355]

33. Hinds PS, Nuss SL, Ruccione KS, et al. PROMIS pediatric measures in pediatric oncology: valid and clinically feasible indicators of patient-reported outcomes. Pediatric blood & cancer. 2013;60(3):402–408. [PubMed: 22829446]

34. Reeve BB, McFatrich M, Mack JW, et al. Expanding construct validity of established and new PROMIS Pediatric measures for children and adolescents receiving cancer treatment. Pediatric blood & cancer. 2020;67(4):e28160. [PubMed: 31904157]

35. Schwarz G Estimating the dimension of a model. The annals of statistics. 1978;6(2):461–464.

36. Berlin KS, Williams NA, Parra GR. An introduction to latent variable mixture modeling (part 1): Overview and cross-sectional latent class and latent profile analyses. J. Pediatr. Psychol 2014;39(2):174–187. [PubMed: 24277769]

37. Lo Y, Mendell NR, Rubin DB. Testing the number of components in a normal mixture. Biometrika. 2001;88(3):767–778.

38. Nylund KL, Asparouhov T, Muthén BO. Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. Structural equation modeling: A multidisciplinary Journal. 2007;14(4):535–569.

39. Wang M-C, Deng Q, Bi X, Ye H, Yang W. Performance of the entropy as an index of classification accuracy in latent profile analysis: a monte carlo simulation study. Acta Psychologica Sinica. 2017.

40. Cuenca-García M, Huybrechts I, Ruiz JR, et al. Clustering of multiple lifestyle behaviors and health-related fitness in European adolescents. J. Nutr. Educ. Behav 2013;45(6):549–557. [PubMed: 23702476]

41. Mitchell TB, Steele RG. Latent profiles of physical activity and sedentary behavior in elementary school-age youth: Associations with health-related quality of life. J. Pediatr. Psychol 2017.

42. Pan C-Y, Chang Y-K, Tsai C-L, Chu C-H, Cheng Y-W, Sung M-C. Effects of physical activity intervention on motor proficiency and physical fitness in children with ADHD: An exploratory study. Journal of attention disorders. 2017;21(9):783–795. [PubMed: 24827938]

43. Hamari L, Lähteenmäki PM, Pukkila H, et al. Motor performance in children diagnosed with cancer: A longitudinal observational study. Children. 2020;7(8):98. [PubMed: 32824254]

44. Levy E, Samoilenko M, Morel S, et al. Cardiometabolic risk factors in childhood, adolescent and young adult survivors of acute lymphoblastic leukemia–a petale cohort. Scientific reports. 2017;7(1):1–9. [PubMed: 28127051]

45. Carson V, Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC public health. 2011;11(1):1–10. [PubMed: 21199570]

46. Carle AC, Bevans KB, Tucker CA, Forrest CB. Using nationally representative percentiles to interpret PROMIS pediatric measures. Qual. Life Res 2021;30(4):997–1004. [PubMed: 33201388]

47. Fisher RS, Rausch JR, Ferrante AC, et al. Trajectories of health behaviors across early childhood cancer survivorship. Psycho-oncology. 2019;28(1):68–75. [PubMed: 30402997]

48. Arsenault JE, Moursi M, Olney DK, Becquey E, Ganaba R. Validation of 24-h dietary recall for estimating nutrient intakes and adequacy in adolescents in Burkina Faso. Maternal & child nutrition. 2020;16(4):e13014. [PubMed: 32337835]

49. Kohl III HW, Fulton JE, Caspersen CJ. Assessment of physical activity among children and adolescents: a review and synthesis. Preventive medicine. 2000;31(2):S54–S76.

50. Raber M, Swartz MC, Santa Maria D, et al. Parental involvement in exercise and diet interventions for childhood cancer survivors: a systematic review. Pediatr. Res 2016;80(3):338. [PubMed: 27064243]

Table 1.

Descriptive statistics of demographic, medical, cardiometabolic, physical performance, and emotional functioning variables

	Number of Participants (%) N=397
Sex	
Female	204 (51.39%)
Male	193 (48.61%)
Age at Survey Assessment	
Mean ± Standard Deviation	15.08 ± 1.78
Range	11.27 - 17.93
Age at Pediatric Functional Assessment	
Mean ± Standard Deviation	15.28 ± 1.73
Range	12.02 - 17.99
Age at Diagnosis	
Mean ± Standard Deviation	3.30 ± 2.39
Range	0.02 - 10.24
Ethnicity	
Hispanic	23 (5.79%)
Non-Hispanic Black	72 (18.14%)
Non-Hispanic White	281 (70.78%)
Other	21 (5.29%)
Caregiver Informant	
Parent	364 (96.04%)
Other	15 (3.96%)
Diagnosis	
Bone tumor	2 (0.50%)
CNS tumor	69 (17.38%)
Hodgkin lymphoma	7 (1.76%)
Leukemia	134 (33.75%)
Neuroblastoma	28 (7.05%)
Non-Hodgkin lymphoma	14 (3.53%)
Other Carcinoma	30 (7.56%)
Retinoblastoma	57 (14.36%)
Soft tissue sarcoma	24 (6.05%)
Wilms tumor	32 (8.06%)
Treatment Modalities	
Surgery	394 (99.24%)
Chemotherapy	327 (82.37%)
Alkylating agents	232 (58.44%)
Anthracycline	216 (54.41%)
Platinum agents	109 (27.46%)
Vinca alkaloids	264 (66.50%)

Retinoic acid	15 (3.78%)
Methotrexate	145 (36.52%)
Corticosteroids	136 (34.26%)
Radiation	126 (31.74%)
Brain	75 (18.89%)
Chest	66 (16.62%)
Abdomen	62 (15.62%)
Pelvis	58 (14.61%)
Income	
Less than $20,000	45 (12.50%)
$20,000-$39,999	70 (19.44%)
$40,000-$59,999	61 (16.94%)
$60,000-$79,999	46 (12.78%)
$80,000-$99,999	38 (10.56%)
Over $100,000	100 (27.78%)
Health Insurance	
Yes	359 (95.99%)
No	10 (2.67%)
Non-US Resident/Citizen	5 (1.34%)
Highest Grade of Caregiver Completing Survey	
Completed High School or Less	57 (15.83%)
Some college or training after high school	96 (26.67%)
College or post-graduate level	207 (57.50%)
Cardiometabolic Risk Indicators	**Mean ± Standard Deviation**
Average resting heart rate	75.40 ± 11.86
Diastolic blood pressure	113.5 ± 10.20
Systolic blood pressure	67.35 ± 8.09
Body mass index percentile	67.45 ± 30.96
Body fat percentage	28.72 ± 14.30
Physical Performance Indicators	
Motor proficiency	38.64 ± 30.36
Physiological cost index	0.09 ± 0.03
Physical activity exertion	12.09 ± 3.84
Average respirations	17.54 ± 1.96
Emotional Functioning Indicators	
Pain interference T-score	44.24 ± 11.04
Anxiety T-score	44.99 ± 11.76
Depressive symptoms T-score	44.01 ± 10.70

Table 2.

Descriptive statistics for the model indicators across profiles for best fitting model

	Guideline	Inactive-Unhealthy-Diet		Active-Sedentary-Unhealthy-Diet	
		Mean	**SD**	**Mean**	**SD**
Days per week physically active > 60 minutes	7 days per week	2.98	2.23	5.10	1.65
Days per week strengthen/tone muscles	2-3 days per week	0.68	0.97	4.80	1.30
Average hours per day sitting	-	7.60	2.96	6.55	3.06
Average hours per day sitting to watch TV or videos	<2 hours	3.98	1.68	3.43	1.54
Average hours per day on computer or play computer games outside of school	<2 hours	2.89	2.02	2.54	1.88
Overall dietary score (0-100)	100	53.59	9.81	55.14	10.17

Note. SD=standard deviation

Table 3.

Mean differences in cardiometabolic risk, physical performance, and psychological functioning across latent classes

	Inactive-Unhealthy Diet N=299		Active-Healthy Diet N= 98			
	Mean	**SD**	**Mean**	**SD**	**T-value**	**p-value**
Cardiometabolic Risk Indicators						
Average resting heart rate	76.54	12.00	71.95	10.74	0.0008	<.001
Diastolic blood pressure	67.59	8.34	66.63	7.28	0.3125	0.31
Systolic blood pressure	113.64	10.57	113.10	9.00	0.6518	0.65
% elevated blood pressure	N=96	32.11%	N=32	32.65%		1.00
Body mass index percentile	66.70	31.48	69.76	29.34	0.3951	0.40
% with overweight/obesity	N=125	41.81%	N=47	47.96%		0.29
Body fat percentage	29.21	14.34	27.22	14.12	0.2543	0.25
% elevated body fat	N=71	26.01%	N=17	19.10%		0.20
Physical Performance Indicators						
Motor proficiency	34.73	29.15	50.40	31.02	<.0001	<.001
Physiological cost index	0.09	0.03	0.09	0.03	0.2733	0.27
Physical activity exertion	12.25	3.92	11.59	3.58	0.1448	0.15
Average respirations	17.57	1.99	17.47	1.90	0.6648	0.67
Emotional Functioning Indicators						
Pain interference T-score	43.92	11.27	45.17	10.35	0.3359	0.34
Anxiety T-score	45.16	11.94	44.48	11.25	0.6220	0.62
Depressive symptoms T-score	44.25	11.09	43.34	9.50	0.4690	0.47

Note. SD=standard deviation

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Table 4.

Chronic health conditions, cardiometabolic, physical performance, and emotional health factors associated with health behavior profiles

	Odds Ratio	95% Confidence Interval	P-Value
Reference Class: IU			
Global Chronic Health Conditions CTCAE Grade ≥2	1.19	0.65- 2.18	0.58
Cardiometabolic Risk Indicators			
Average resting heart rate	0.97	0.95- 1.00	0.05
Diastolic blood pressure	0.99	0.95- 1.03	0.70
Systolic blood pressure	0.98	0.95- 1.02	0.35
Body mass index percentile	1.01	0.99- 1.02	0.30
Body fat percentage	1.00	0.97- 1.03	0.80
Physical Performance Indicators			
Motor proficiency	1.01	1.00- 1.02	0.01
Physiological cost index	0.01	0.00-149.1	0.35
Physical activity exertion	0.91	0.84- 0.99	0.04
Average respirations	0.92	0.79- 1.06	0.26
Emotional Functioning Indicators			
Pain interference T-score	1.03	1.00- 1.06	0.07
Anxiety T-score	1.00	0.96- 1.03	0.90
Depressive symptoms T-score	1.00	0.96- 1.04	0.90

Note. IU=Inactive-unhealthy-diet class