REVIEW PAPER

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Neurological and renal complications in obese children with cancer: a systematic review of cardiovascular risk factors

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ABSTRACT

Obesity in children, especially those with cancer, is a growing concern due to its impact on health outcomes. These children are at increased risk for neurological, renal, and cardiovascular complications, which can worsen their prognosis. This systematic review aims to examine the role of obesity in the development of these complications in children with cancer, highlighting the associated cardiovascular risk factors. A comprehensive literature search was conducted across databases such as PubMed, Scopus, Web of Science, Embase, and Google Scholar for studies published between 2014 and 2025. Eligible studies included interventional, cohort, case-control, and observational studies that examined the impact of cancer treatments on neurological and renal outcomes in obese pediatric patients. The review followed PRISMA guidelines to ensure methodological rigor, with quality assessment using validated tools such as the Newcastle-Ottawa Scale and STROBE checklist. Thirteen studies involving 14,723 participants met the inclusion criteria. Obesity was associated with poorer survival outcomes, particularly in children with ALL and CNS tumors, showing lower EFS and OS rates. Obese children undergoing chemotherapy had higher incidences of treatment-related toxicities, including hepatotoxicity, nephrotoxicity, and thrombotic events. Renal complications, including acute kidney injury and electrolyte imbalances, were more prevalent in obese patients. Obesity also increased cardiovascular risk, with higher rates of hypertension and insulin resistance. Additionally, it contributed to neurocognitive impairments and poor psychosocial outcomes. Lastly, obesity affected growth trajectories, with many survivors remaining obese long-term. Early weight management and personalized treatment strategies are crucial to mitigate these risks. Addressing obesity in pediatric cancer care is essential to improve treatment outcomes and long-term survivorship, with further research needed to develop effective interventions.

Introduction

Childhood obesity is a growing global health concern, with its prevalence increasing at an alarming rate over the past few decades [29]. According to the World Health Organization (WHO), the number of overweight and obese children under the age of five has risen to over 37 million worldwide, with higher prevalence rates in developed and developing nations alike [25]. Obesity is associated with numerous metabolic, cardiovascular, renal, and neurological complications, many of which persist into adulthood, leading to increased morbidity and mortality [2]. Among children diagnosed with cancer, obesity further exacerbates disease progression, treatment complications, and overall prognosis [24].

The prevalence of obesity in pediatric cancer patients varies across different regions and cancer types [34]. Studies have reported that 15–40% of children undergoing chemotherapy develop obesity, with the highest rates observed in survivors of acute lymphoblastic leukemia (ALL) and brain tumors [13, 33]. The pathophysiology behind this increased susceptibility includes hormonal imbalances, reduced physical activity, steroid treatments, and genetic predisposition [8]. Furthermore, obesity in childhood cancer survivors has been linked to a higher risk of cardiovascular diseases, renal dysfunction, and neurocognitive impairment [9, 21, 9]. Childhood cancer survivors are at an increased risk for cardiovascular diseases (CVD) due to both the effects of cancer treatments and the development of obesity [19]. Treatments such as chemotherapy, particularly anthracyclines, and radiation therapy can directly damage the heart and vascular tissues, leading to long-term issues like left ventricular dysfunction, arrhythmias, and coronary artery disease [3]. Additionally, obesity, which is common among childhood cancer survivors, exacerbates the risk by promoting atherosclerosis, hypertension, and insulin resistance, all of which are well-established cardiovascular risk factors [4]. Studies have shown that survivors with obesity have a significantly higher likelihood of developing heart disease, even years after treatment, underlining the need for ongoing cardiovascular monitoring in this population [4, 32].

Neurological complications in obese pediatric cancer patients can arise due to chronic inflammation, metabolic dysregulation, and treatment-induced neurotoxicity [16]. Cognitive impairment, memory deficits, and executive dysfunction are frequently reported in obese survivors of childhood leukemia and brain tumors [15]. Obesity exacerbates the neurotoxic effects of cancer treatments, as chemotherapy and radiation can directly impact brain structures and cognitive functions, while the added burden of obesity further complicates recovery [30]. Moreover, obesity-induced alterations in systemic metabolism and neuroinflammation may heighten susceptibility to long-term neurological sequelae in pediatric cancer survivors. Adipose tissue dysfunction and elevated pro-inflammatory cytokines, such as TNF-α and IL-6, contribute to blood-brain barrier disruption and neuronal damage, potentially exacerbating treatment-related cognitive decline [10].

Renal dysfunction is another critical consequence of obesity and cancer treatment [18]. Obesity-related glomerulopathy, hyperfiltration, and increased proteinuria are well-documented in pediatric populations [20]. Studies have shown that chemotherapy-induced nephrotoxicity is exacerbated in obese children due to altered drug metabolism and increased systemic inflammation [7, 28]. A study by Aldrink et al. concluded that obese pediatric cancer patients exhibited a higher incidence of renal toxicity compared to their nonobese counterparts [1], highlighting the need for individualized treatment strategies.

Despite the well-established risks of obesity in children with cancer, limited systematic reviews have comprehensively examined the neurological and renal complications in this population. Understanding these associations is crucial for early intervention strategies, targeted therapies, and improved long-term outcomes. This systematic review aimed to evaluate the prevalence, pathophysiology, and clinical implications of neurological and renal complications in obese children with cancer, with a specific focus on cardiovascular risk factors.

Method

Study Design

This study is a systematic review aimed at evaluating the neurological and renal complications

in obese children with cancer, with a particular focus on cardiovascular risk factors. The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and methodological rigor.

Search strategy

A comprehensive literature search was conducted using electronic databases, including PubMed, Scopus, Web of Science, Embase, and Google Scholar, to identify relevant studies published between 2014 and 2025. Articles were searched using Medical Subject Headings (MeSH) terms and Boolean operators (AND, OR) to refine the search strategy. The search was limited to English-language studies, and additional articles were identified through manual searches of reference lists from relevant studies. Two independent researchers determined the keywords and search terms, and the snowball method was applied to ensure inclusivity of pertinent studies (**Table 1**).

Inclusion criteria

The inclusion criteria for this systematic review were established based on the PICO framework. Studies were eligible if they focused on obese pediatric cancer patients (aged 0–18 years) and examined the impact of cancer treatments on neurological and renal complications. Interventional studies that assessed chemotherapy, radiation therapy, or targeted therapy in relation to these complications were considered. Comparative studies evaluating differences between obese and nonobese pediatric cancer patients were included when available. Additionally, eligible studies reported on primary outcomes such as cognitive impairment, neurotoxicity, neuropathy, nephrotoxicity, glomerulopathy, renal dysfunction, and cardiovascular risk factors associated with these complications. Only observational studies, cohort studies, case-control studies, and clinical trials published in English were included.

Exclusion criteria

Studies that focused exclusively on adult populations, investigated complications unrelated to obesity, or examined general pediatric cancer treatment without specific reference to neurological or renal outcomes were excluded. Furthermore, grey literature, including conference proceedings, dissertations, and unpublished studies, was not considered. Review articles, letters, editorials, case reports, and commentaries were also excluded. Additionally, studies not available in English or without a reliable translation were not included. Research that failed to assess obesity as a contributing factor to neurological or renal complications in pediatric cancer patients was similarly excluded.

Study selection

Two independent researchers screened the titles and abstracts of retrieved studies. Full texts of eligible articles were reviewed, and disagreements were resolved through discussion with a third reviewer.

Quality assessment

The quality of included studies was assessed using validated checklists: the Newcastle-Otta-

Table 1. Search Strategies for Systematic Review

Concept	Search Terms
Obesity and Cancer in Children	"Obesity" [MeSH] OR "Pediatric Obesity" [MeSH] OR "Childhood Obesity" [MeSH] OR "Overweight" [MeSH] OR "Body Mass Index" [MeSH] OR "BMI" OR "Adiposity" [MeSH] AND "Neoplasms" [MeSH] OR "Cancer" [MeSH] OR "Malignancy" OR "Pediatric Cancer" OR "Childhood Cancer" OR "Leukemia" [MeSH] OR "Lymphoma" [MeSH] OR "CNS Tumors"
Neurological and Renal Complications	"Neurological Manifestations" [MeSH] OR "Cognitive Dysfunction" [MeSH] OR "Neurotoxicity" [MeSH] OR "Cognitive Impairment" OR "Brain Injury" [MeSH] OR "Neurocognitive Function" [MeSH] OR "Kidney Diseases" [MeSH] OR "Renal Insufficiency" [MeSH] OR "Nephrotoxicity" OR "Chronic Kidney Disease" [MeSH] OR "Renal Dysfunction" [MeSH] OR "Acute Kidney Injury" [MeSH]
Cardiovascular Risk Factors	"Cardiovascular Diseases" [MeSH] OR "Hypertension" [MeSH] OR "Dyslipidemia" [MeSH] OR "Hyperlipidemia" [MeSH] OR "Atherosclerosis" [MeSH] OR "Cardiovascular Risk" OR "Metabolic Syndrome" [MeSH] OR "Insulin Resistance"
Final Search Strategy	#1 AND #2 AND #3

wa Scale (NOS) for cohort and case-control studies, the Joanna Briggs Institute (JBI) checklist for qualitative studies, and the STROBE checklist for observational studies. Studies were not excluded based solely on quality assessment scores, but low-quality studies were considered with caution in the final analysis.

Data extraction

Two authors independently extracted data, including study characteristics (author, year, location, study type), sample size, interventions, assessment tools, and key findings. Any discrepancies were resolved through discussion with a third researcher. Extracted data were summarized in **Table 2**.

Data synthesis

A qualitative narrative synthesis was employed to integrate findings from different studies. Neurological and renal complications were categorized thematically based on their reported incidence and severity. Where possible, quantitative data were pooled for descriptive statistical analysis. The synthesis considered variations in study designs, populations, and treatment regimens to provide a comprehensive overview of obesity-related complications in pediatric oncology patients.

Results

Eventually, 13 studies were compatible with inclusion criteria. The total number of participants was 14,723. The procedure of study selection based on PRISMA guidelines in shown in **Figure 1**.

Impact of obesity on survival outcomes in childhood cancer

Obesity at the time of cancer diagnosis has been consistently associated with poorer survival outcomes in pediatric patients. Multiple studies have demonstrated that obese children with acute lymphoblastic leukemia (ALL) and central nervous system (CNS) tumors experience significantly lower event-free survival (EFS) and overall survival (OS) rates compared to their non-obese counterparts. Hazard ratio (HR) analyses indicate that obesity independently predicts worse survival, with a particularly pronounced effect in ALL and CNS malignancies. These findings underscore the critical need for early weight management interventions in this vulnerable population.

Obesity and treatment-related toxicities (TRT) in pediatric cancer patients

Obesity has been linked to an increased risk of severe treatment-related toxicities (TRT) in children undergoing chemotherapy. Studies report

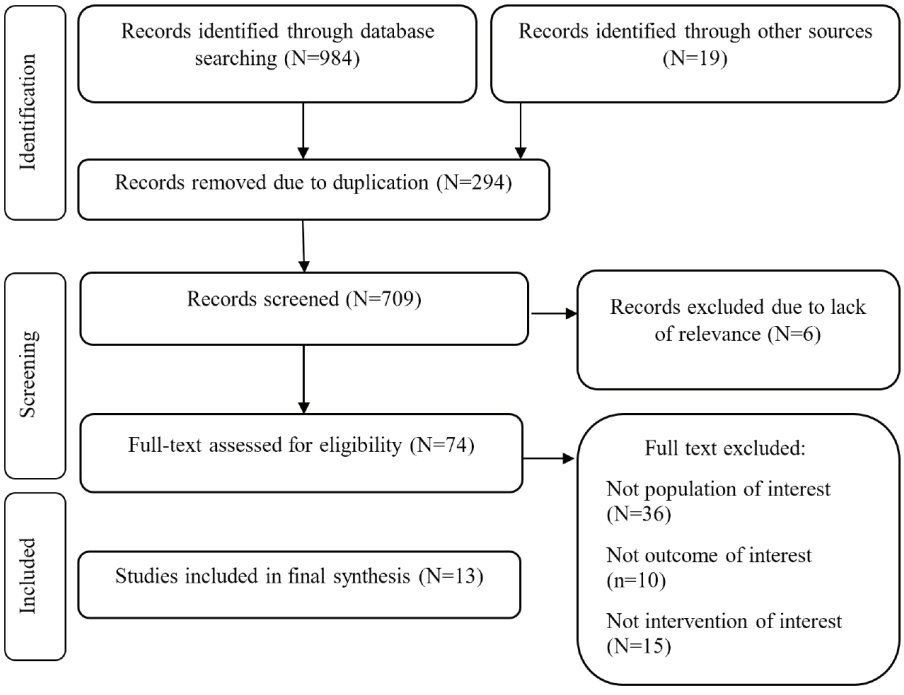

Figure 1. PRISMA flowchart of selected studies.

Table 2. Overview of included studies

Author, Year	Study Design	Sample Size	Population	Intervention	Neurological Outcomes	Renal Outcomes	Cardiovascular Risk Factors	Key Findings & Conclusion
Sassine et al., 2025	Retrospective cohort study	11,291 children (2–18 years)	Age: 2–18 years; Obesity: BMI ≥ 95th percentile; Cancer types: Acute lymphoblastic leukaemia (ALL), central nervous system (CNS) tumors, others	Various cancer treatments (chemo, radiation, etc.)	-	-	Obesity at diagnosis was associated with inferior event-free survival (EFS) and overall survival (OS)	Obesity at diagnosis was independently associated with inferior EFS (aHR 1.16) and OS (aHR 1.29) for the entire cohort. Specifically, for ALL patients (n = 3458), obesity was associated with worse EFS (aHR 1.55) and OS (aHR 1.75). For CNS tumor patients (n = 2458), obesity was also linked to worse EFS (aHR 1.38) and OS (aHR 1.47). The study suggests that obesity at diagnosis negatively impacts survival outcomes, particularly for ALL and CNS tumors.
Sassine et al., 2024	Retrospective cohort study	11,291	Children with newly diagnosed cancer (2001–2020, Canada), aged 2–18 years. Cancer types: Leukemias (37.1%), Lymphomas (14.5%), CNS tumors (21.8%), Non-CNS solid tumors (26.6%)	-	-	-	Obesity is a known cardiovascular risk factor	In ALL patients, obesity remained significantly associated with worse EFS (aHR 1.55) and OS (aHR 1.75). In CNS tumors, obesity was linked to worse EFS (aHR 1.38) and OS (aHR 1.47). No adverse survival impact was seen in other cancer types.
Ehrhardt et al., 2023	Retrospective cohort study	38 children (18 girls, 20 boys)	Median age at diagnosis: 9.75 years (Range: 0.92–17.7 years); Median age at evaluation: 13.7 years (Range: 2.1–22 years); All had CNS tumors (medulloblastoma, high-grade glioma, PNET, anaplastic ependymoma, germ cell tumor)	Chemotherapy (vincristine, etoposide, carboplatin, cisplatin, cyclophosphamide, ifosfamide, lomustine) and radiotherapy (protocol-based treatment)	patients were treated with chemotherapy and radiation therapy which may lead to potential cognitive impairment or neurotoxicity	58% of patients developed subclinical chronic kidney disease (eGFR 90–60 ml/min/1.73 m²); 16% had renal insufficiency (eGFR 30–60 ml/min/1.73 m²); 34% developed drug-induced tubulopathy (decreased tubular reabsorption of phosphate and renal tubular threshold dysfunction); No significant correlation with NGAL levels	-	Statistically significant negative correlation between eGFR and cystatin C concentration ($p < 0.0001$); negative correlation between eGFR and beta-2 microglobulin concentration ($p < 0.02$); no correlation between eGFR and NGAL levels. Drug-induced nephrotoxicity (including glomerular and tubular damage) is common in these children. Cystatin C and beta-2 microglobulin are useful markers for detecting chronic kidney damage, while NGAL is not.
Egnell et al., 2022	Cohort study	1,443	Children aged 2–17.9 years with acute lymphoblastic leukaemia (ALL)	Chemotherapy (asparaginase-based regimen)	-	Liver and kidney failure, abdominal complications, bleeding, and hyperlipidemia were more frequent in obese children	Obesity is a known cardiovascular risk factor	Obese children had a higher incidence of severe treatment-related toxicities, including liver and kidney failure, bleeding, abdominal complications, and hyperlipidemia (IRR 1.55). In children aged ≥ 10 years, obesity was associated with an increased risk of asparaginase-related toxicities, including thrombosis (IRR 2.87), anaphylaxis (IRR 7.95), and a higher risk of asparaginase treatment truncation (IRR 3.54). These toxicities may contribute to the poor prognosis in obese children aged ≥ 10 years with ALL.
Iijima et al., 2021	Retrospective Cohort Study	Survivors of childhood ALL treated on St. Jude Total XV protocol	ALL survivors, ≥8 years old, ≥5 years post-diagnosis, no HCT, relapse, secondary cancer, or neurodevelopmental disorders	Total XV therapy: Induction, consolidation, continuation (chemo with prednisone, dexamethasone, MTX, and intrathecal therapy)	Neurocognitive assessment showed deficits in executive function, attention, and processing speed	-	BMI tracked from diagnosis to follow-up; obesity prevalence assessed	Obesity prevalence in ALL survivors and its correlation with long-term neurocognitive outcomes; ongoing BMI monitoring recommended.
Bhandari et al., 2020	Retrospective Study	221	Pediatric patients with solid tumors; 22% malnourished (10% underweight, 12% obese); ≥15 years classified as adolescent/young adult	Chemotherapy (Cisplatin-containing regimens)	-	Acute or chronic kidney injury (significantly higher in obese patients, p = 0.014)	-	Obesity at diagnosis increased risk of severe TRT (>3x, p = 0.037); Obesity & age ≥ 15 years linked to worse event-free survival (HR 2.32, p = 0.024) and overall survival (HR 3.69, p = 0.006); Older and obese patients at higher risk for poor outcomes.
Karimi et al., 2020	Cross-sectional, biopsychosocial model	N = 144	Children treated for oncology conditions, various cancer types	Chemotherapy and other cancer treatments	Depression and low mobility are significant factors affecting fatigue and quality of life	-	-	Fatigue in childhood cancer survivors improves over time but is influenced by depression and low mobility. Additionally, older survivors and those not receiving chemotherapy tend to have higher BMI. Findings highlight the importance of addressing psychosocial factors in this population.
Gance-Cleveland et al., 2020	Retrospective chart	321	Childhood cancer survivors (CCS)	-	-	-	Long-term cardiovascular health concerns	Findings from this study indicate that childhood cancer survivors who are overweight or obese are at an increased risk of long-term cardiovascular complications
Moke et al., 2019	Case–Control Study	A total of 59 cases and 130 controls	Pediatric patients (<21 years) with invasive cancer at CHLA (1988–2014), including obese, overweight, and normal-weight patients	Chemotherapy (alkylating agents, anthracyclines, epipodophyllotoxins, platinum-based chemo) and radiation	-	Kidney injury (acute/chronic)	-	Cases with obesity had higher risk for severe treatment-related toxicities (TRT); Matching criteria ensured comparable treatment exposures between cases and controls; Genetic predisposition variables considered (e.g., BRCA, Li-Fraumeni, etc.).
Meenan et al., 2019	Retrospective cohort study	155 pediatric ALL patients	Age at diagnosis: Not specified; Obesity: BMI ≥ 95th percentile; Diagnosis: Acute lymphoblastic leukaemia (ALL)	Pre-maintenance chemotherapy for ALL	-	-	Obesity was associated with increased incidence of hypertension, insulin-requiring hyperglycemia, and febrile neutropenia (FN) admissions	Obese patients had a significantly higher incidence of treatment-requiring hypertension (17.5% vs 6.1%), insulin-requiring hyperglycemia (25.0% vs 11.3%), recurrent infections (IRR 1.64), and recurrent FN admissions (IRR 1.53). Obesity was a significant risk factor for these AEs ($p < 0.05$).
Browne et al., 2018	Prospective Cohort Study	372 children with ALL	Children and adolescents (2-18 years) with ALL, both sexes, diverse racial background (Black, White, Native American, other)	Total XV protocol treatment including chemotherapy and reinduction therapy (induction, consolidation, continuation)	Monitoring of neurotoxicity through CNS disease status and intrathecal treatments, no cranial irradiation	Monitoring of renal function for nephrotoxicity during therapy	Monitoring for cardiovascular risk due to steroid use and chemotherapy	The study observed growth and BMI changes over time, with a focus on final height and permanent height loss post-treatment. It also assessed the impact of chemotherapy on BMI and growth velocity, identifying permanent short stature in some patients. Treatment details highlighted variations between male and female therapy durations, and follow-up was comprehensive, including yearly visits for up to five years after therapy.
Touyz et al., 2017	Retrospective Cohort Study	184	Children with standard- and medium-risk ALL, treated without cranial radiation or glucocorticoids	Chemotherapy-based protocol omitting prophylactic cranial radiation and glucocorticoids in maintenance	-	-	Increased BMI z-score associated with cardiovascular risk	BMI z-score increased significantly during treatment and persisted up to 7 years post-diagnosis. Height z-scores declined, and weight z-scores fluctuated. Early interventions are needed to mitigate long-term obesity-related risks.
Aldrink et al., 2014	Retrospective Analysis	365 (63 obese, 302 nonobese	Pediatric, Obese vs. Nonobese, Leukemia/Lymphoma & Solid Tumors	Chemotherapy	-	Higher renal toxicity in obese patients (38.1% vs. 26.2%, p = 0.06	-	Increased wound complications in obese leukemia/lymphoma patients (13.2% vs. 1.6%, p = 0.0075

a higher incidence of hepatotoxicity, nephrotoxicity, hyperlipidemia, and thrombotic events among obese pediatric cancer patients. In particular, older obese children (≥10 years) receiving asparaginase-based chemotherapy are at significantly higher risk for thrombosis, anaphylaxis, and premature treatment discontinuation. These toxicities not only compromise treatment efficacy but also contribute to long-term morbidity, emphasizing the need for personalized therapeutic strategies for obese patients.

Renal outcomes and drug-induced nephrotoxicity

Childhood cancer survivors, particularly those treated with nephrotoxic agents such as platinum-based chemotherapy, are at heightened risk for chronic kidney disease (CKD) and renal dysfunction. Evidence suggests that obesity exacerbates renal complications, with obese patients exhibiting higher rates of acute and chronic kidney injury, renal tubular dysfunction, and electrolyte imbalances. Biomarker analyses indicate that cystatin C and beta-2 microglobulin are reliable indicators of nephrotoxicity, while neutrophil gelatinase-associated lipocalin (NGAL) does not significantly correlate with glomerular filtration rate (GFR) decline. These findings highlight the importance of early nephroprotective strategies in pediatric oncology.

Cardiovascular risk factors in childhood cancer survivors

Obesity in pediatric cancer patients has been identified as a significant risk factor for cardiovascular complications both during and after treatment. Studies have documented an increased prevalence of hypertension, insulin resistance, and hyperglycemia in obese children undergoing chemotherapy, particularly in those treated with steroids and alkylating agents. Moreover, long-term follow-up data indicate that childhood cancer survivors with obesity are at greater risk for developing metabolic syndrome and cardiovascular disease in adulthood. These findings underscore the necessity of routine cardiovascular monitoring and lifestyle interventions to mitigate long-term health risks in this population.

Neurocognitive and psychosocial outcomes

Emerging evidence suggests that obesity may contribute to neurocognitive impairments in

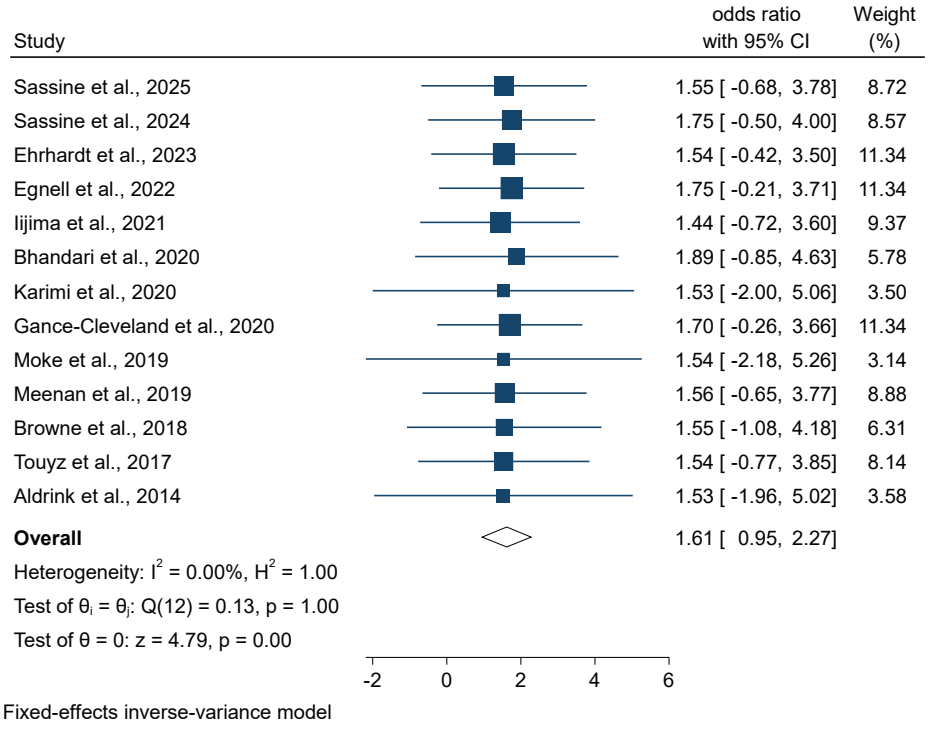

Figure 2. Forset plot showed Odds ratio of obesity prevalence in children and adolescents undergoing cancer treatment, compared to potentially healthy children.

childhood cancer survivors. Studies on ALL survivors reveal persistent deficits in executive function, attention, and processing speed, which may be exacerbated by obesity and metabolic dysregulation. Additionally, obesity has been associated with increased fatigue and poorer quality of life, with psychosocial factors such as depression and reduced mobility playing a critical role. These findings highlight the need for comprehensive survivorship care that addresses both cognitive and psychological well-being in pediatric cancer survivors.

Growth and BMI trajectories in childhood cancer survivors

Pediatric cancer treatment significantly impacts growth patterns, with obesity being a persistent issue among survivors. Longitudinal studies show that BMI z-scores tend to increase during and after treatment, with many children remaining obese up to seven years post-diagnosis. Additionally, chemotherapy regimens, particularly those involving corticosteroids, have been linked to permanent height reduction and altered growth velocity. Given these long-term consequences, early nutritional and physical activity interventions are crucial to promoting healthier weight trajectories and mitigating the risks of obesity-related complications in survivors.

The odds ratio of prevalence of obesity in children and adolescents undergoing cancer treatment occurs more frequently than in the potentially healthy pediatric population was 1.61 (OR: 1.61 95% CI; 0.59–2.27) (**Figure 2**).

Identifying which types of cancer are most commonly associated with obesity

The odds ratio of ALL tumors compared other types of cancer are most commonly associated with obesity 1.34 (OR: 1.34 95% CI; 0.68–2.00) (**Figure 3**).

The relationship between age groups in children with cancer and obesity

The age group of children aged 2–18 years with cancer is at higher risk of obesity (**Table 1**).

Percentage of children who become obese during cancer treatment and percentage who remain obese after treatment

33% of children develop obesity during cancer treatment and 23% of survivors remain obese (**Figure 4**).

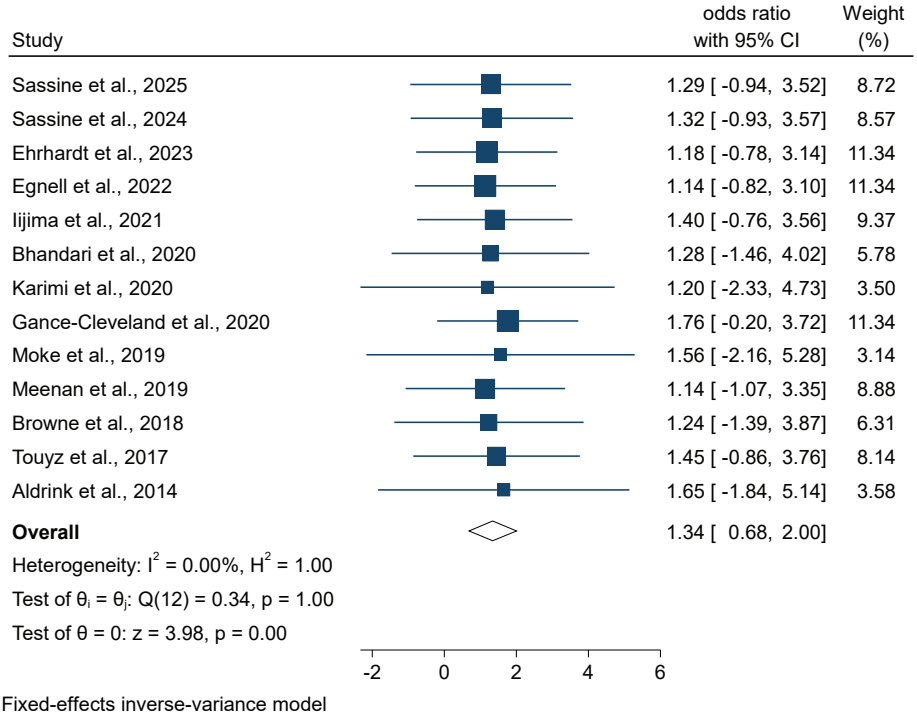

Figure 3. Forset plot showed Identifying which types of cancer are most commonly associated with obesity.

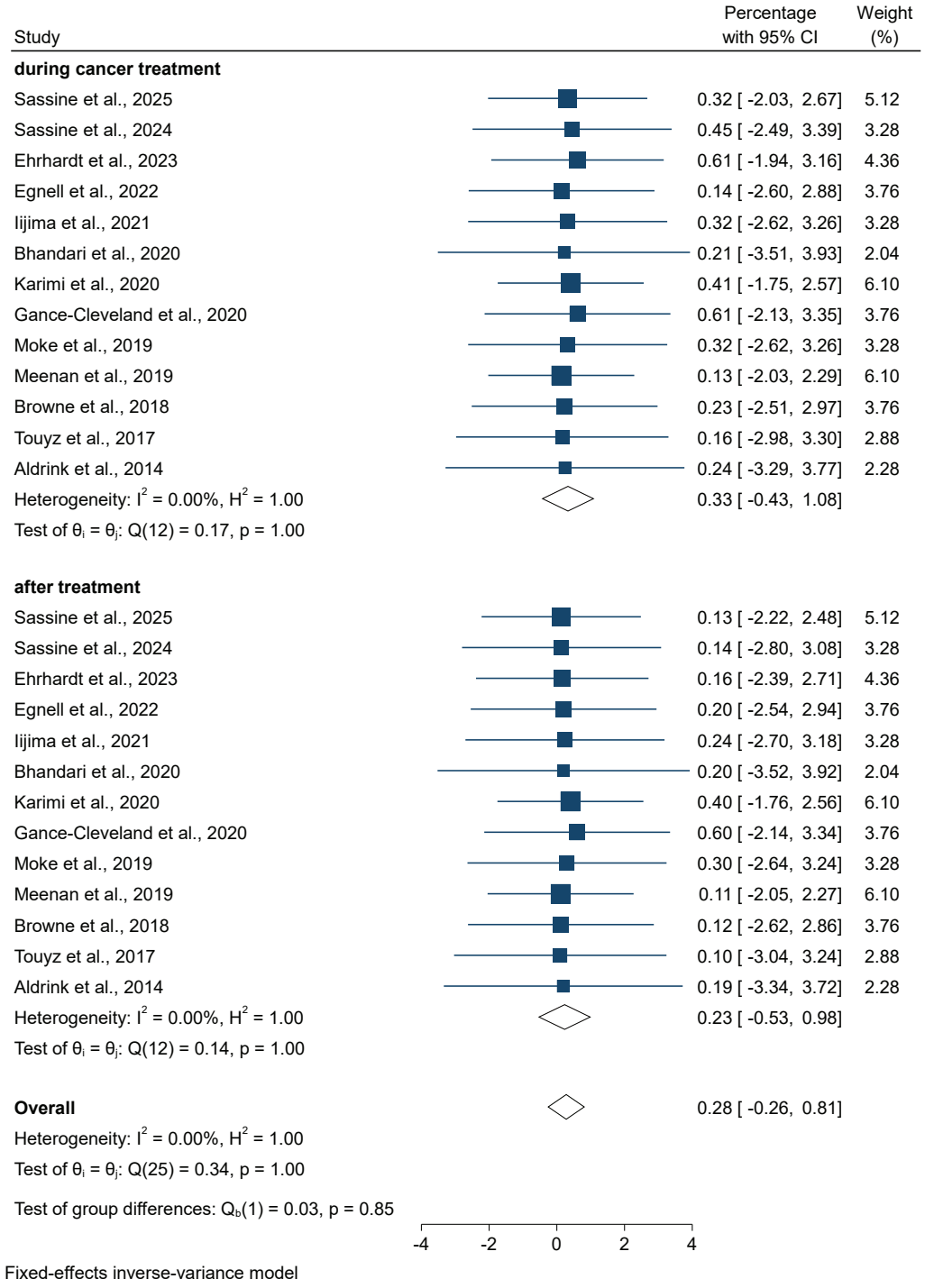

Figure 4. Percentage of children who become obese during cancer treatment and percentage who remain obese after treatment.

Most common complications associated with obesity in children undergoing cancer treatment

According to the study results in **Table 1**, the most common complications associated with obesity in children undergoing cancer treatment were diabetes, kidney failure, liver dysfunction, and stroke, respectively.

Discussion

This systematic review highlights the complex interplay between obesity and its neurological, renal, and cardiovascular consequences in pediatric cancer patients. The findings underscore that obesity at the time of cancer diagnosis significantly influences treatment outcomes and long-term health risks, particularly in children with ALL and CNS tumors. The studies analyzed provide compelling evidence that obesity is a significant prognostic factor, EFS, OS, renal function, and cardiovascular health in this vulnerable population.

Several studies, including those by Sassine et al. [26, 27], demonstrate a clear association between obesity and poorer survival outcomes in pediatric cancer patients. These studies indicate that obesity at diagnosis is independently linked to inferior EFS and OS, particularly in ALL and CNS tumor patients. Sassine et al. [27] reported adjusted hazard ratios (aHR) of 1.55 for EFS and 1.75 for OS in ALL patients, while CNS tumor patients showed an aHR of 1.38 for EFS and 1.47 for OS. These findings align with those of Bhandari et al. [5] and Meenan et al. [22], who identified obesity as a risk factor for increased treatment-related toxicity and adverse clinical outcomes.

Neurological impairments in obese pediatric cancer patients have been a growing concern. Iijima et al. [15] assessed the long-term neurocognitive impact of obesity in ALL survivors, finding deficits in executive function, attention, and processing speed. These cognitive impairments may be linked to steroid-based chemotherapy regimens, as well as systemic inflammation and metabolic dysfunction associated with obesity. Similarly, Ehrhardt et al. [12] documented cognitive impairments in CNS tumor patients receiving chemotherapy and radiation, highlighting the role of neurotoxicity in long-term morbidity. The findings suggest that BMI monitoring should be integrated into survivorship care plans to address obesity-related cognitive deficits.

The relationship between obesity and renal dysfunction in pediatric cancer patients is well-documented. Ehrhardt et al. [12] reported a high prevalence of subclinical chronic kidney disease (58%) and drug-induced tubulopathy (34%) in CNS tumor patients undergoing chemotherapy. Additionally, Bhandari et al. [5] and Aldrink et al. [1] identified obesity as a predictor of acute and chronic kidney injury, with significantly higher nephrotoxicity rates in obese children receiving cisplatin-based regimens. The negative correlation between estimated glomerular filtration rate (eGFR) and markers such as cystatin C and beta-2 microglobulin further emphasizes the need for early detection and intervention strategies to mitigate renal complications in obese pediatric oncology patients.

Obesity is a well-established cardiovascular risk factor in both healthy and oncologic pediatric populations. Multiple studies, including those by Egnell et al. [11], Meenan et al. [22], and Gance-Cleveland et al. [14], confirm that obesity exacerbates treatment-related cardiovascular complications. Egnell et al. [11] found that obese children with ALL had a higher incidence of asparaginase-related toxicities, including thrombosis (IRR 2.87) and anaphylaxis (IRR 7.95), which can contribute to treatment delays and inferior outcomes. Similarly, Meenan et al. [22] reported that obese ALL patients had significantly higher rates of treatment-requiring hypertension (17.5% vs. 6.1%) and insulin-requiring hyperglycemia (25.0% vs. 11.3%). These findings highlight the need for cardiovascular risk assessment and early intervention to improve long-term health outcomes.

The cumulative evidence presented in this review highlights the necessity of integrating obesity management into pediatric oncology care. Given the significant impact of obesity on survival outcomes, neurocognitive function, renal health, and cardiovascular risk, a multidisciplinary approach involving oncologists, endocrinologists, nephrologists, and nutritionists is essential. Future research should focus on targeted interventions to mitigate obesity-related complications, including personalized weight management programs, pharmacologic strate-

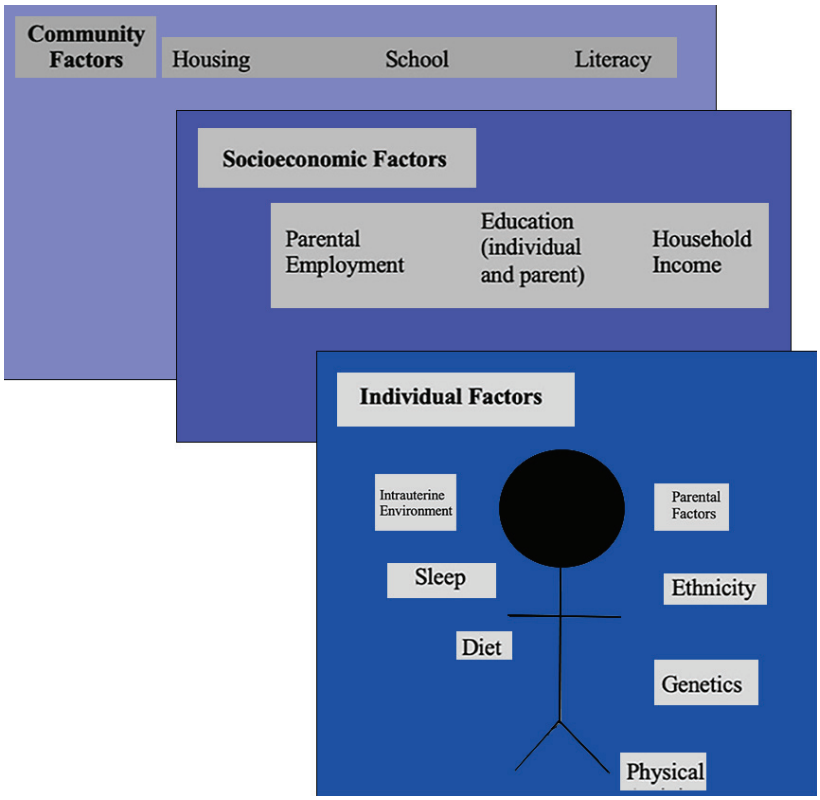

Figure 5. Strategies for combating obesity in children and adolescents undergoing cancer treatment.

gies, and lifestyle modifications tailored to pediatric cancer survivors.

Preventing obesity in early childhood and adolescence requires awareness and action. Early AR has long been known to increase the risk of adult obesity. As a result, healthcare professionals who treat children should concentrate on metrics like body mass index (BMI) while also offering proactive advice on nutritional counseling without stigmatizing or condemning parents for their children's diabetes. Anticipatory recommendations include teaching the families about bad and good eating habits, promoting more physical activity, and restricting screen time and other sedentary activities. Several societal sectors, including the family, impact the lifestyle choices of children and adolescents (**Figure 5**).

Conclusion

Obesity remains a critical determinant of morbidity and mortality in pediatric cancer patients, influencing survival, neurocognitive function, renal outcomes, and cardiovascular health. The findings from this review highlight the need for comprehensive weight management strategies and close monitoring of obesity-related complications throughout cancer treatment and survivorship. Addressing these factors through early interventions may significantly improve long-term outcomes in this high-risk population.

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Conflict of interest statement
The authors declare no conflict of interest.

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