Factors affecting weight and body composition in childhood cancer survivors – cross sectional study

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Abstract

Background Due to improved efficacy of antitumour treatment in the general population, there are increasingly more childhood cancer survivors. However, some of these survivors are at risk of distant complications including cardiovascular disease. We aimed to examine the risk of overweight/obesity and abnormal body composition in a large group of patients from our paediatric oncology centre. **Method** We used anthropometric methods and electrical bioimpedance to assess these features, and then determined their association with disease and treatment. **Results** We found patients treated for leukaemia/lymphoma (especially boys) had significantly higher rates of overweight/obesity compared to the other patient groups. In contrast, overweight/obesity was more common in girls among patients treated for solid tumours. Patients treated for leukaemia/lymphoma were characterized by a higher body fat content compared to those treated for solid tumours and controls. During treatment for cancer patients had a higher percentage of muscle mass deficiency compared to those in the control group. Our regression analysis showed time from completion of treatment, gender, and type of therapy (radiotherapy, megachemotherapy) were associated with body weight and body composition including fat and muscle content. **Conclusions** We recommend pediatricians and general practitioners should actively try to detect and prevent cardiovascular disease among childhood cancer survivors.

Background

The efficacy of comprehensive antitumour treatment has improved over the years, leading to an increase in the number of childhood cancer survivors. Nonetheless, cancer survivors should be monitored for relapse of underlying disease, secondary tumours, and late complications of therapy, including endocrine complications such as obesity and diabetes [1, 2]. Indeed, the risk of obesity was shown to be higher among cancer survivors than their healthy siblings (e.g. relative risk, 1.8; 95% CI, 1.7-2.0 in Childhood Cancer Survivor Study [3]). Persons with central nervous system (CNS) tumours, those treated for acute lymphoblastic leukaemia (ALL), and patients after transplantation of hematopoietic cells are especially at risk for this type of complication [4]. Cardiovascular disease, obesity and diabetes are one of the main responsible for increased mortality and morbidity among childhood cancer survivors as compared to non-cancer population (reviewed in [5]). The task of detecting these complications falls to family physicians, pediatricians and pediatric oncologists and the patients themselves.

To identify these complications diverse measures are used. The most universal marker for the diagnosis of overweight and obesity is the standardized body mass index (BMI-SDS); its calculations should be based on updated country norms [6]. For assessment of fat and muscle mass content, bioelectrical impedance analysis (BIA) is used. The results obtained from BIA correlate with data from the reference dual-energy X-ray absorptiometry (DXA) method [7, 8]. BMI is very easy to assess, but it is an anthropometric parameter and therefore should be considered as a surrogate measure for fatness. Although BMI correlates with percentage body fat assessed by BIA or DEXA, the correlation between both parameters is not sufficiently accurate to truthfully reflect the amount of fat in the body in a particular subject. Therefore if fatness is the true risk factor for longevity and health, then BMI is only an approximation and is therefore inadequate [9]. On the other hand BIA results can be affected by hydration level, skin temperature, exercise, the use of diuretics, female menstruation, and the need to void the bowel and bladder before the assessment.

The studies carried out so far concerning cardiovascular disease risk factors in childhood cancer survivors have typically involved small groups of patients, or patients with one diagnosis, and typically use only BMI or BIA/DXA for assessment of obesity and excessive body fat. With this in mind, in our cross-sectional study, we aimed to identify

clinical factors that affect body weight and body fat and muscle content in people who are currently treated or have had cancer in childhood. We examined body weight and body fat and muscle content in a large group of patients from our paediatric oncology centre using anthropometric methods and electrical bioimpedance. We then examined the relationship(s) of these factors with features associated with the disease and/or its treatment. The data obtained may be useful in identifying people at risk of developing cardiovascular disease after childhood cancer treatment and for future prevention.

Patients And Methods

Patients

This study was carried out at the Department of Paediatric Oncology and Haematology at the Medical University of Bialystok, Poland from 2014 to 2017 (approved by the Bioethics Committee, consent number: 153-798883L). It was designed as a cross-sectional study evaluating body mass and bioimpedance during and after cancer treatment in childhood. The tests were performed during regular follow-up visits in all patients who met the inclusion criteria. The study inclusion criteria were: diagnosis of cancer according to the Polish Group for the Treatment of Leukaemias/Lymphomas and Solid Tumours criteria; Polish nationality; aged 2–22 years; good general condition at the time of the study; consent of the parents/guardians and/or the patient themselves for inclusion in the study; and in post-treatment patients, remission of the underlying disease. Study exclusion criteria were: chromosomal disorders, mental disorders (including eating disorders such as anorexia, bulimia), hormonal and autoimmune disorders including thyroid and adrenal gland disorders, celiac disease, and diabetes. The control group (aged 4- 23 years, matched in terms of age and sex with the group of patients after cancer treatment) was composed of siblings/families of patients with cancer, volunteers, and children admitted to the clinic for reasons other than cancer. The group included patients in whom cancer, chromosomal, autoimmune, hormonal, and psychiatric disorders were excluded. Parents/guardians and/or subject themselves provided consent for inclusion in the study.

The study group was divided into the following four subgroups, according to the type of cancer and whether they were undergoing active treatment or not: 1) patients currently undergoing intensive/maintenance treatment for leukaemia or Hodgkin's/non-Hodgkin's lymphoma, 2) patients after completion of treatment for leukaemia/lymphoma (> 1 year after therapy termination), 3) patients currently undergoing treatment for solid tumours, 4) patients after completion of treatment for solid tumours (> 1 year after therapy termination). Patients treated with steroids were considered those who were receiving a dose of 60mg/m² daily of prednisone or equivalent for a minimum of 30 days. Radiation therapy involved a minimum dose of 12 Gy, and may have been applied to the CNS, neck, mediastinum, abdominal cavity, or total body.

Anthropometric methods

Anthropometric parameters including age, sex, height, weight, and BMI standardized deviation score (BMI-SDS) were evaluated in all subjects. The disease-associated parameters evaluated in the group of cancer patients/survivors were: type of cancer, treatment regimen used, elapsed time since therapy termination, use of radiotherapy, history of steroid treatment, and history of hematopoietic stem cell transplantation (HSCT).

The examination included measurements of height (cm, Harpenter's stage-meter) and weight (kg) conducted by trained members of the study team. BMI (kg/m²) and BMI-SDS values were calculated and coded as follows:

underweight = BMI-SDS < -1; normal weight = $-1 \leq \text{BMI-SDS} < +1$; overweight = $+1 \leq \text{BMI-SDS} < +2$, obesity = $+2 \geq \text{BMI-SDS}$ [1].

Bioelectrical impedance analysis (BIA)

BIA was used to assess the body composition (device: InBody 370 Biospace, USA). All tests were performed by two trained members of our team (MSZ and JD). Body fat content in grams (FAT), percentage body fat (PBF), and skeletal muscle mass (SMM) were chosen among the parameters obtained from the device. All these parameters were referenced to age and gender norms entered into the device software; thus, each result was given as below, normal, or above the norm.

Data presentation and statistical analysis

Data are presented as means and standard deviation (SD) or medians and interquartile range (IQR), and rates of incidence of a given characteristic in the evaluated group of children. Due to non normal distribution of most of the variables, non parametric tests were used. To find the differences between the groups of patients and controls ANOVA was performed and post-hoc pair-wise comparisons. Correlations were performed using the Spearman's test. Multivariate linear regression was used to evaluate the impact of clinical features on BMI-SDS, PBF, and SMM. A $p < 0.05$ was considered statistically significant. Statistical analysis were made in Statistica 13 (Dell, USA).

Results

The size of the individual patient groups and the distribution of gender and age are presented in Table 1. Children currently undergoing treatment for leukaemia / lymphoma or solid tumours were significantly younger than those in the other groups (ANOVA, post-hoc and pair-wise tests - Table 1). Patients who had completed cancer treatment (groups 2 and 4) did not differ in age from the control group. There was no difference among groups in terms of gender distribution. The median time from the end of anticancer treatment was significantly shorter in patients treated for leukaemia/lymphoma than in those treated for solid tumours (Table 1).

Changes in body mass index

The BMI-SDS and the incidence of normal and abnormal body weight composition in each group are summarized in Table 2. Patients who had completed treatment for leukaemia/lymphoma were characterized by significantly higher BMI-SDS than the other patient groups (ANOVA, post-hoc and pair-wise tests). Likewise, patients with leukaemia/lymphoma (both during and after treatment) had statistically significantly higher overweight and obesity rates compared to the control group and those with solid tumours (Table 2).

We found different BMI-SDS and overweight / obesity rates among patients with cancer according to gender. In the control group, the overall prevalence of overweight/obesity was similar in boys and girls (22.2% vs. 26.4%, respectively; $p = 0.8$). Meanwhile, after treatment for leukaemia/lymphoma, overweight/obesity were more common among boys than girls (50.0% vs. 35.0%, respectively; $p < 0.01$). However, the opposite relationship was observed in patients following treatment for solid tumours: overweight/obesity was more common in girls than boys (21.2% vs. 7.5%, respectively; $p < 0.01$).

The BMI-SDS was then analyzed in groups of patients after antineoplastic treatment according to the time from the end of therapy. Within five years after the end of treatment for both leukaemia/lymphoma and solid tumours, patients had a higher BMI-SDS and higher overweight/obesity rates; however, these differences were not statistically significant.

Further analyses were made by studying the effects of therapy on the current BMI-SDS and overweight/obesity rates. After treatment including radiotherapy, patients with leukaemia/lymphoma were characterized by significantly higher BMI-SDS and more cases of overweight/obesity than those treated without irradiation (medians 1.34 vs 0.46 $p = 0.02$; cases: 19.3%/33.8% vs. 13.2%/25.6%; $p = 0.04$, respectively). There were no statistically significant differences in BMI-SDS values and overweight/obesity rates in patients treated for leukaemia/lymphoma or solid tumors with or without HSCT.

Bioelectrical impedance analysis

The percentage of patients with normal and abnormal amount/percentage of fat and muscle is shown in Table 3. Patients with leukaemia/lymphoma (both during and after treatment) were characterized by higher body fat content compared to those following treatment for solid tumours and control subjects (Table 3). Patients currently undergoing treatment for leukaemia/lymphoma and solid tumours had higher rates of SMM deficiency compared to those in the control group (Table 3).

The above variables were subsequently analyzed according to gender. During treatment for leukaemia/lymphoma, girls showed greater fat mass compared to boys (PBF 71.8% vs. 61.5%), as well as compared to girls and boys in the control group (30.7% vs. 29.7%). However, after treatment for leukaemia/lymphoma, boys had a higher fat mass compared to girls (the proportion of results above the norm was 55.6% in boys vs. 36.3% in girls). After treatment of solid tumours, girls were more likely to have an excessive amount and PBF compared to boys (PBF 42.4% vs. 20.0%).

Further analysis was made by dividing the patients after antineoplastic treatment into subgroups according to the time elapsed since the end of therapy. After treatment for solid tumours, there was a significantly higher proportion of patients with excessive body fat i.e.25% in the ≤ 5 years group compared to 10.4% in the >5 years group ($p < 0.01$). Similar ratio was found in PBF (41.6% vs 25.0%, $p < 0.01$). Regarding muscle tissue in patients after treatment for leukaemia/lymphoma, its deficiency was observed more frequently in patients with ≤ 5 years since completion of therapy compared to >5 years (48.5% vs. 31.8%, respectively, $p = 0.01$); inverse relationships were noted in patients after treatment for solid tumours (SMM deficiency ≤ 5 years vs. >5 years: 29.1% vs. 56.2%, respectively, $p < 0.01$).

The effects of irradiation and megachemotherapy with HSCT on body fat and muscle content were also analyzed. After treatment for leukaemia/lymphoma, both the mass and PBF were higher in patients treated with radiotherapy compared to those treated without radiotherapy (variables normalized to age and gender): excess of FAT was observed in 40 (64.5%) patients irradiated and 47 (38.8%) patients without irradiation ($p < 0.01$); excess PBF was found in 47 (77.0%) patients and 66 (54.5%) patients with and without irradiation, respectively ($p < 0.05$). The proportions were similar in patients after treatment of solid tumours, but were only statistically significant for PBF: 14 / 37.8% vs. 8 / 22.2% with and without irradiation, respectively ($p < 0.05$). Regarding SMM, in the group of patients after treatment for solid tumours, the proportion of patients with muscle mass deficiency increased among irradiated subjects (22/37 [59%] vs. 12/36 [33%] patients, respectively; $p < 0.05$).

Megachemotherapy with HSCT resulted in a greater amount and PBF in patients after treatment for leukaemia/lymphoma than those without HSCT (FAT excess: 29/51 [56.8%] patients with HSCT vs. 58/132 [43.9%] patients without HSCT; PBF excess: 38/51 [74.5%] vs. 75/132 [56.8%], respectively; $p < 0.01$) but not after treatment for solid tumours. In patients after treatment with megachemotherapy (for leukemias/lymphomas or solid tumors), higher rates of muscle mass deficiency was observed compared to patients treated without this method, but these differences were not statistically significant.

Factors influencing the variability in body mass index and fat and muscle mass

The factors influencing the BMI-SDS and body fat and muscle mass were analyzed in patients following anticancer treatment. Age of the patients was considered as confounding factor. Only statistically significant correlations with probable clinical significance were examined.

Following treatment for solid tumours, there was a negative correlation between time since the end of therapy and BMI-SDS ($r = -0.24$; $p < 0.05$). Interestingly, the correlation was stronger after grouping of patients according to gender ($r = -0.42$ in females and $r = -0.38$ in males, $p < 0.05$; Figure 1). This means the BMI-SDS decreased over time since completion of antineoplastic treatment in this group of patients. However, we did not find a similar relationship in patients after treatment for leukaemia/lymphoma, even after considering gender. In contrast, the PBF decreased with time after completion of therapy in both groups, but the correlation was only statistically significant after treatment for leukaemia/lymphoma ($r = -0.28$ in females and $r = -0.22$ in males, $p < 0.05$; Figure 2).

There was a positive correlation between SMM and time from treatment completion both after treatment for leukaemia/lymphoma and for solid tumours ($r = 0.37$ and $r = 0.23$, respectively; $p < 0.05$). However, taking into account the patient's age at the time of the study, the correlation remained positive only in the group after treatment for leukaemia/lymphoma ($r = 0.21$): the correlation became negative in those after treatment for solid tumours ($r = -0.26$; $p < 0.05$). Thus, muscle mass increases over time after treatment for leukaemia/lymphoma and decreases after treatment for solid tumours.

We then developed regression models to explain the variation in body weight, as well as fat and muscle mass. The time from treatment completion and gender explained 46% of the variability in BMI-SDS after solid tumour treatment ($R^2 = 0.46$, $p < 0.01$). The time from treatment completion, irradiation, gender, and age of diagnosis of cancer explained 29% of the variability in PBF after treatment for leukaemia/lymphoma ($R^2 = 0.30$, $p < 0.01$). The time from treatment completion and irradiation were the strongest contributing factors. A similar model with time from completion of therapy and gender explained 63% of the variability in PBF after treatment for solid tumours ($R^2 = 0.64$, $p < 0.00$); meanwhile, gender and the use of megachemotherapy explained 49% of the variability in FAT in this group of patients ($R^2 = 0.50$, $p < 0.00$).

We also performed regression analysis in a combined group of patients after treatment for both leukaemia/lymphoma and solid tumours (256 patients in total). Only the time elapsed from the end of treatment explained the variability in the BMI-SDS in this group ($R^2 = 0.16$, $p < 0.01$). The time from the treatment completion and gender explained the variability in PBF ($R^2 = 0.33$, $p < 0.00$). Finally, the time from the end of treatment, gender, the use of HSCT, and the age of cancer diagnosis explained muscle content after treatment for leukaemia/lymphoma or solid tumours ($R^2 = 0.84$, $p < 0.00$).

Discussion

The enormous success that has occurred in the treatment of childhood cancer can be diminished by the distant effects of therapy. One such complication may be cardiovascular disease caused by, among others, excessive weight gain and body fat increase. In our study, we identified gender, type of cancer, type of treatment, and time from treatment completion as factors affecting the body weight and composition of a large group of patients both during and after the end of childhood cancer treatment.

In our study, we found higher rates of overweight/obesity and excessive body fat after treatment for leukaemia and lymphoma among boys; however, after treatment for solid tumours, higher rates were observed in girls. Indeed, the effect of gender on the occurrence of cardiovascular risk factors after treatment of cancer has been diverse. For example, in a large group of Danish survivors, obesity was more common in the female population, and predisposing factors were younger age, high BMI at diagnosis, and cranial radiotherapy [10]. In another observation, many years after treatment for ALL, young men had a higher proportion of obesity and fat content compared to age-matched controls [11]. Meanwhile, Blijdorp et al. [12] made interesting observations when evaluating patients after cancer treatment: BMI was higher in women, irrespective of time since treatment, as opposed to men where it increased with time after the end of treatment. In addition, the percentage of fat was only higher than controls in men. Furthermore, as in our study, in a group of non-Hispanic white survivors, 12 years after diagnosis of leukaemia/lymphoma, men and not women had a higher fat content including trunk fat compared to the control group [13]. Most reports indicate that cranial radiation is the cause of the body composition and weight disorders in patients after treatment for ALL, but this type of treatment is becoming less commonly used in standard ALL therapy. However, another study showed women after ALL treatment without cranial radiation did not differ in BMI and body fat from control subjects, and in men, there was no difference between groups after treatment with and without radiation [14]. Nonetheless, for greater reliability of such results, it is necessary to stratify large groups of patients according to multiple clinical features.

Of the many types of cancers that occur in children, leukaemia and lymphoma seem to be the biggest risk factors for overweight. This is likely due to the use of glucocorticoids, as well as to irradiation of both the CNS and in HSCT. In a prior analysis of persons after ALL treatment, the main factor affecting the current body weight was body weight at diagnosis and its increase during therapy [15]. In a similar group of patients, only initial weight was a predictor of overweight/obesity after treatment, not age at diagnosis, gender, or dose of steroids [16]. It should be kept in mind that the effect of the initial BMI on the distant values of this indicator is so great that, in such an analysis, other factors may not have statistical significance [10]. Therefore, in our regression analysis, we did not include the initial BMI-SDS as a factor influencing its current values.

Traditionally, it is assumed that patients with solid tumours, even after treatment, have fewer problems with overweight/obesity than those with ALL, mainly due to the lack of high doses of steroids used in solid tumour regimens. However, many years after the treatment of nephro- or neuroblastoma, an excessive amount of body fat and characteristics of metabolic syndrome were associated with abdominal radiation [17]. Although, people who receive abdominal radiation are also characterized by a more advanced stage of the disease and also receive more chemotherapy cycles than those with clinical tumour stage I or II.

Murphy and colleagues [18] performed a study similar to ours, but on a smaller group of patients. In their analysis, patients both during and after treatment had a higher percentage of fat compared to those in the control group. Interestingly, there were no statistically significant differences in body composition depending on the type of cancer in the group currently being treated. However, based on current data, it is not entirely clear which methods are best

for cardiovascular risk assessment among cancer survivors. Specifically, the underestimation of obesity with BMI versus DXA may affect men exposed to abdominal/pelvic radiation. Furthermore, among former Children's Oncology Group patients, overweight/obesity was found in 39% of subjects, but was not observed more frequently than in the control group without cancer [19]. Moreover, it is important to note the high prevalence of sarcopenic obesity during and after treatment for leukaemia limits the utility of BMI as an indicator of obesity [20].

Among the analyzed factors affecting the development of overweight/obesity, we found radiation therapy and the use of HSCT were important. Similarly, a previous study showed among 276 patients after completion of tumour treatment, 47.8% were overweight/obese after cranial radiation compared to 30.4% of those treated without radiation [21]. We did not notice differences in BMI, although patients treated with radiation had a higher percentage of body fat evaluated by electrical bioimpedance. Another authors showed the BMI and waist circumference were closely correlated with the dose of cranial radiation [22]. Perhaps the threshold that leads to the development of obesity after radiotherapy in ALL is a dose of ≥ 20 Gy [23]. Still, the question remains as to whether the omission of radiotherapy in modern ALL treatment in children reduces or completely eliminates the occurrence of excess body mass and body fat.

In our study, treatment with HSCT was a risk factor for excessive body fat but not overweight/obesity. Similarly, Bizzarri et al. [24] found a high proportion of patients with central obesity but normal BMI after HSCT due to hematologic malignancies, especially those who received total body irradiation and (in contrast to us) with long time after transplantation. This phenomenon was associated with the lipodystrophic and sarcopenic phenotype of these patients [25]. Meanwhile, a long-term prospective follow-up of patients after allogeneic HSCT indicated that BMI decreases over time after transplantation, but this effect is more likely to be due to lean mass rather than fat mass loss [26]. Initial BMI prior to transplantation is a strong predictor of this index after transplantation, like in standard therapy. In another study after transplantation, high rates of central obesity and body fat were associated with the use of total body irradiation, but the presence of graft-versus-host disease resulted in less body fat [27].

In summary, we still do not know what contributes more to the occurrence of obesity after recovery from cancer — the disease itself or the treatment? The origin of obesity in cancer survivors is not fully explained, but likely includes physical inactivity, damage to the hypothalamus and endocrine organs, and resistance to insulin and leptin, among others (reviewed by [2]). In addition, the effect of clinical factors (including CNS irradiation and the use of glucocorticoids) on the occurrence of obesity after antineoplastic treatment has been shown to be stronger than that of genetic factors [28]. Some authors suggest obesity in patients after cancer treatment adversely affects their quality of life, including chemotherapy-induced peripheral neuropathy [29], while others found no relationship between quality of life after completed antitumour therapy and body weight [30].

The strength of our analysis is the creation of a regression model that explains which factors affect body mass, fat and muscle after treatment of childhood cancer. This model shows the factors that determine the occurrence of overweight/obesity and abnormal body composition in cancer survivors. The limitations of our study are the small number of children included who were currently undergoing treatment of solid tumours, the difficulties with stratification according to glucocorticoid therapy, and a lack of prospective studies.

The occurrence of excessive body weight and body fat after cancer can and must be prevented. An early intervention based on family participation in patient lifestyle intervention has been proposed previously [31]. We recommend pediatricians and family physicians should actively detect and prevent cardiovascular disease in childhood cancer survivors.

Declarations

Ethics approval and consent to participate

The study design was approved by the Ethics Committee at the Medical University of Bialystok in accordance with the Declaration of Helsinki (No 153-798883L). Signed informed consent was obtained from patients and their parents/guardians.

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MSZ and MKR designed the study, MSZ and WL were a major contributors in writing the manuscript, MSZ and JD collected and analysed the patient's data. All authors read and approved the final manuscript.

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Not applicable

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Tables

Table 1. Number of patients, sex and age in examined and control subgroups.

	1 Leukemias / Lymphomas during therapy	2 Leukemias / Lymphomas after treatment termination	3 Solid tumors during therapy	4 Solid tumors after treatment termination	5 Control group	Statistical analysis
Number of patients	84	183	12	73	89	
Age of the assessment mean $\pm$ SD	8.22 $\pm$ 4.7	13.46 $\pm$ 4.0	9.81 $\pm$ 4.8	13.91 $\pm$ 4.9	13.38 $\pm$ 4.60	group 1 vs 2, 4, 5*** group 3 vs 2, 4, 5***
Sex: female / male N / N % / %	32 / 52 38.0% / 62.0%	77 / 106 42.0% / 58.0%	7 / 5 58.3% / 41.7%	33 / 40 45.2% / 54.8%	52 / 37 58.4% / 41.5%	no statistical differences
Diagnosis	ALL, AML, HD, NHL	ALL, AML, HD, NHL	ES, OS, RMS	WT, NBL, RMS, ES, OS, GCTs, LCH	Healthy siblings, volunteers, hematologic disturbances suspected and excluded	
Age of diagnosis mean $\pm$ SD	7.44 $\pm$ 4.9	7.32 $\pm$ 4.5	9.03 $\pm$ 4.6	5.27 $\pm$ 4.7	-	group 3 vs 1,2,4* group 4 vs 1-3**
Time from treatment termination (median, 25-75 IQR)		4.38 $\pm$ 3.4		7.40 $\pm$ 4.7		***
Steroids in treatment N %	84 100%	166 90.7%	1 8.3%	6 8.2%	-	
Radiation in treatment N %	9 10.7%	62 33.9%	6 50.0%	37 50.7%	-	
Megachemotherapy in treatment N %	0 0.0%	51 27.9%	6 50.0%	12 16.4%	-	

ALL - acute lymphoblastic leukemia, AML - acute myeloid leukemia, HD - Hodgkin disease, NHL - non-Hodgkin lymphoma, RMS - rhabdomyosarcoma. LCH -Langerhans cell histiocytosis, NBL - neuroblastoma, OS - osteosarcoma, GCTs - germ cell tumors, WT - Wilms tumor, ES - Ewing Sarcoma

*p=0.01, **p=0.001, ***p=0.0001

Table 2. Standardized body mass index and percentages of normal and abnormal weight in patients subgroups.

	1 Leukemias / Lymphomas during therapy	2 Leukemias / Lymphomas after treatment termination	3 Solid tumors during therapy	4 Solid tumors after treatment termination	5 Control group	Statistical analysis
BMI-SDS median (25-75 percentile)	0.38 (-0.61 – 1.39)	0.70 (-0.21 – 2.12)	-0.06 (-0.67 – 2.45)	0.07 (-0.55 – 0.59)	0.18 (-0.49– 0.96)	group 2 vs 4** group 2 vs 5**
Underweight N %	10 11.9%	12 6.6%	2 16.7%	8 11.0%	5 5.6%	group 1 vs 3-5** group 2 vs 3-5 **
Normal weight N %	45 53.6%	91 49.7%,	7 58.3%,	55 75.3%,	62 69.7%	
Overweight N %	17 20.2%,	28 15.3%	0 0%	4 5.5%,	11 12.4%	
Obesity N %	12 14.3%	52 28.4%;	3 25%	6 8.2%;	11 12.4%	

**p=0.001

Table 3. Percentages of patients with normal and abnormal amount of fatt or muscle mass in bioimpedance analysis.

	1 Leukemias / Lymphomas during therapy	2 Leukemias / Lymphomas after treatment termination	3 Solid tumors during therapy	4 Solid tumors after treatment termination	5 Control group	Statistical analysis
FAT g <N / N / >N	8.3% / 45.2% / 46.4%	16.9% / 35.5% / 47.5%	8.3% / 66.6% / 25%	24.6% / 60.0% / 15%	24.7% / 51.6% / 23.5%	group 2 vs. 5 *
PBF % <N / N / >N	3.5% / 30.9% / 65.4%	9.2% / 28.9% / 61.7%	8.3% / 33.3% / 58.3%	13.6% / 56.2% / 30.1%	12.3% / 57.3% / 30.3%	group 2 vs. 4* group 2 vs 5*
SMM <N / N / >N	61.9% / 33.3% / 4.8%	43.2% / 49.2% / 7.6%	91.6% / 8.3% / 0.0%	46.6 % / 50.7 % / 2.7 %	35.9% / 59.5 % / 4.5%	group 1 vs 5* group 3 vs 5*

N = normal

*p=0.01

Figures

Figure 1

The significant, negative correlation between standardized body mass index and time from treatment termination for solid tumors in females ($r=-0.42$, $p<0.05$).

Figure 2

The significant, negative correlation between percentage of fat mass (% PBF) and time from treatment termination for leukemias/lymphomas in females ($r=-0.28$, $p<0.05$).