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Health-related characteristics of Cancer survivors according to body mass index: a secondary data analysis

In Hoe Ku[1] and Sangjin Ko[2*]

Abstract

Background Lifestyle habits and genetic factors of cancer survivors can lead to recurrence or development of new cancers. Obesity in cancer survivors increases the risk of cancer recurrence and affects mortality. This study aimed to analyze the relationship between health-related characteristics and related factors in cancer survivors by classifying obesity according to body mass index.

Methods This study is a secondary data analysis research study using 5-year data, including 3-year (2016–2018) and 2-year data (2019–2020) from the 7th and 8th Korea National Health and Nutrition Examination Survey, respectively. This study targeted 4,553,669 cancer survivors who had completed past or early cancer management, did not have active cancer, or were receiving treatment for advanced cancer but were not in the terminal stage. Data were analyzed with complex sample descriptive statistics, cross-tabulation analysis and chi-square test and t-test. Lastly, complex sample multivariable linear regression analysis using IBM SPSS software.

Results Demographic factors such as gender (t = -4.07, p <.001), marital status (t = 4.20, p <.001), and economic activity (t = -3.27, p =.002); health factors such as hypertension (t = 9.07, p <.001) and hemoglobin level (t = 5.29, p <.001); and nutrition-related characteristics such as frequency of breakfast (t = -6.49, p <.001), sodium intake (t = 2.41, p =.17), vitamin D intake (t = 3.02, p =.003), and vitamin C intake (t = -3.43, p =.001) were significant factors influencing cancer survivors' BMI.

Conclusions The results of this study are significant as they confirm the relationship between health-related characteristics and BMI in cancer survivors. The study comprehensively identified and presented various factors related to BMI in the lives of cancer survivors. To control BMI in cancer survivors, it is necessary to assess risk factors and change health behaviors and eating habits. Based on these results, developing and applying health intervention programs to prevent BMI increases and managing obesity in cancer survivors is essential. Promoting health strategies and studying the relationship with BMI in the future will contribute to increasing the healthy survival rate of cancer survivors.

Keywords Cancer survivors, Body mass index, Obesity, Big data, Health status

*Correspondence:
Sangjin Ko
sangjinko@ulsan.ac.kr
[1]Department of Nursing, Ulsan University Hospital, Ulsan, Republic of Korea
[2]Department of Nursing, University of Ulsan, Ulsan, Republic of Korea

Introduction

With the recent development of cancer treatment technology, cancer survival rates continue to increase [1]. However, as cancer can recur or develop new cancers owing to genetic factors and lifestyle habits of cancer survivors, individual health habits are imperative [2, 3]. According to recent American Cancer Society cancer survivorship guidelines, obesity has been shown to significantly affect cancer survivors' health and risk of cancer recurrence [4]. In particular, obesity can induce various systemic changes [5]; however, its relationship with malignant tumors is not well elucidated [6]. Obesity-related hyperinsulinemia, metabolic syndrome, and inflammatory cytokines not only promote cancer progression and metastasis [7], but also affect other health problems, including cardiovascular disease, hypertension (HTN), diabetes, osteoporosis, and quality of life [3, 6]. Obesity causes a range of systemic issues in cancer survivors, and previous studies have reported that obesity increases the risk of cardiovascular disease [8], metabolic syndrome [9], and the likelihood of cancer recurrence [10]. Therefore, modifiable factors such as obesity are crucial components of follow-up care for cancer survivors.

Although maintaining a healthy weight is essential for cancer survivors, several cancer survivors experience weight gain following treatment [4, 6]. Previous studies showed that approximately 62% of breast cancer survivors were overweight or obese [11], and obesity among adult cancer survivors increased faster than in the general population [12]. Obesity in cancer survivors is associated with various physical, mental, social, and emotional functions as well as nutritional factors, such as diet [13, 14], which increase the risk of cancer recurrence and affect mortality [4, 15]. Therefore, to improve healthy weight management and health outcomes of cancer survivors, dietary management such as reduced carbohydrate intake and calorie restriction, and health behaviors such as appropriate physical activities are essential [4, 5, 15]. As the association between obesity and cancer survivors is gaining increasing attention, research on the potential impact of obesity on survival following cancer diagnosis is needed. However, the perception of obesity in cancer survivors has not yet been fully investigated.

Therefore, this study attempted to classify obesity in cancer survivors by body mass index (BMI) using big national data and analyzing the relationship between related factors. Monitoring BMI as an obesity assessment indicator is a useful tool for early identification of obesity/overweight among cancer survivors [8] and helps to group and compare individuals with different characteristics into similar categories. Additionally, BMI has been found to be the only independent predictor of obesity in cancer survivors, with other studies reporting similar results [8–10]. As the survival rate of cancer survivors increases, obesity is becoming a significant health risk, particularly from the perspective of managing cancer survivors as chronic disease patients. Therefore, greater attention should be given to this issue. Identifying the relevance of obesity-related risk factors in cancer survivors and addressing these factors will be crucial in improving health outcomes. Furthermore, the use of national sampling data will be valuable in shaping long-term national health policies [16]. Therefore, this study aimed to identify health-related characteristics of cancer survivors and analyze factors affecting BMI to present basic data on obesity management of cancer survivors.

Methods

Study design

This study is a secondary data analysis research study to investigate the health-related relationship between body mass index in cancer survivors using 5-year data, including 3-year data (2016–2018) from the 7th Korea National Health and Nutrition Examination Survey (KNHANES) period and 2-year data (2019–2020) from the 8th KNHANES period nationwide conducted by the Korea Disease Control and Prevention Agency.

Participants

The sample was extracted using a two-stage stratified cluster sampling. A total of 37,938 participants were enrolled in this study stratification by city, province, region, gender, and age, with all citizens across the country as target groups from 2016 to 2020. To account for the complex sample elements, we used statistical samples to calculate the integrated weights obtained by multiplying the strata, clusters, and appropriate weights by the integrated ratio. In addition, the data integration between periods was calculated by setting the ratio of values corresponding to the survey period as the integrated ratio. A cancer survivor is defined as 'any person living with a cancer diagnosis' [4]. However, due to controversy over whether patients with terminal cancer are considered cancer survivors, this study followed the standards of the National Cancer Survivors Association (ENCSI), which defines a cancer survivor as 'a person living with or after cancer.' The following selection criteria were used: 'Those who have completed past or early cancer management and have no evidence of active disease,' and 'Those who can receive cancer treatment due to advanced disease but are not in the terminal stage' [17]. Of the 37,938 participants, 1,668 adults aged ≥ 19 years and patients with confirmed cancer diagnosis by doctors were sampled. Of them, we finally 804 participants were selected, excluding 864 who responded "yes" to the current cancer prevalence or diagnosed with two or more cancers in the current prevalence. 804 participants are

used for weighted calculations, the unweighted number is 4,553,669.

Measurement

Obesity

Anthropometric measurements were performed by investigators who received training twice to minimize measurement errors. Height was measured using a stadiometer (SECA 225, SECA, Germany), ensuring that all four parts of the body (heels, buttocks, back, and back of the head) were in contact with a vertical board. Measurements were taken with the subject standing in the correct posture, both from the front and the side. Body weight was measured using a scale (GL-6000-20, G-tech, Korea) with the subject breathing normally, eyes facing forward, and arms naturally hanging at the sides. If an examination gown was not worn during the measurement, a correction of -0.5 kg was applied using a correction weight. BMI was defined by measurements, which was calculated as weight (kg) divided by height squared (m^2). We aimed to identify Asian population obesity based on WHO (World health organization) criteria for BMI cutoffs. BMI was categorized as follows: underweight (< 18.5 kg/m^2), normal weight (approximately 18.5–22.9 kg/m^2), overweight (approximately 23.0–24.9 kg/m^2), and obese (≥ 25 kg/m^2) [18].

Demographic characteristics

Demographic characteristics included age, gender, marital status, education level, economic activity, household size, and household income. Gender was categorized as male and female, and marital status was classified into single and married. Education level was classified into below middle school level and over high school level. Economic activity was classified according to presence or absence. Household type was classified into one person and two or more. Household income was divided into above and below the median based on monthly total household income quartile.

Health-related characteristics

Diabetes mellitus (DM), HTN, hours of sleep time, drinking, smoking, cancer screening, subjective health status, Eastern Cooperative Oncology Group Performance Status (ECOG PS), physical activity level, perceived stress level, mental health counseling, hemoglobin level, platelet count, red blood cell (RBC) count, and white blood cell (WBC) count encompassed the health-related factors. DM and HTN were classified according to presence or absence. Sleep time was calculated as the hours of sleep per day. Drinking experience was classified by presence or absence based on more than one glass per day, and smoking experience was classified based on more than five packs (100 cigarettes) of cigarettes throughout life. Medical and cancer screenings were classified according to presence or absence. Subjective health status is assessed by asking, 'How do you think about your health in general?' This is a single question composed of a 5-point Likert scale. The higher the score, the better the subjective health status. Responses were reclassified into three categories: good (good and very good), neutral (average), and bad (bad and very bad). The ECOG PS index evaluates the systemic functional status of cancer patients and is classified from level 0, where all activities are possible, to level 5, where no activities are possible [19]. In this study, participants were asked about difficulties in daily life activities such as work, study, household chores, and leisure activities. The responses were grouped into those with no difficulty or some difficulties (ECOG PS 0–2) and those unable to conduct daily life activities (ECOG PS 3–4). The groups were reorganized into a total of two groups. To calculate physical activity level, information about walking days and walking time was obtained by asking, "During the past week, on which days did you walk at least 10 minutes?". The number of days, ranging from 0 to 7, was recorded, and the walking time was detailed in hours and minutes. Physical activity level was calculated using the walking metabolic equivalent (MET) value, with the following formula: 3.3 × walking days × walking minutes). Physical activity level was classified into light (< 600 MET-min/week), moderate (> 600 MET-min/week), and vigorous (> 1,500 MET-min/week) [20]. Perceived stress level was scored on a 4-point likert scale by answering a single question about how much stress one feels during daily life. Responses were reclassified into a high group (I feel it very much' or 'a lot') and a low group ('a little' or 'I hardly feel it'). Mental health counseling was classified according to presence or absence. Hemoglobin levels were measured using the sodium lauryl sulfate detection method, expressed in grams per deciliter (g/dL). Platelet (10^3/μL) and RBC (10^6/μL) counts were calculated using the DC sheath flow detection method, and WBC counts (10^3/μL) were measured using flow cytometry.

Nutrition-related characteristics

Nutrition-related factors were investigated using diet, dietary supplements, nutrition education, frequency of meals per week (breakfast, lunch and dinner), and levels of energy, carbohydrate, protein, fat, fiber, sodium, vitamin D, and vitamin C as variables. Participants were asked to answer 'yes' or 'no' to the question of whether they were controlling their diet for a special reason (e.g., disease, weight control, etc.). Dietary supplements were classified according to whether supplements were taken 1 day preoperatively. Nutrition education was classified according to nutrition education and counseling conducted outside the previous year. The frequency of

breakfast, lunch, and dinner was categorized as 5–7 times, 3–4 times, 1 or 2 times, and seldom in a week. Daily nutrient intake (energy, carbohydrate, protein, fat, fiber, sodium, vitamin D, and vitamin C) was investigated using an individual 24-h recall method, which recorded the sum of all food and nutrient intake consumed by an individual during the day. Food intake surveys were primarily conducted from Sunday to Thursday, so this should be considered when analyzing trends. Additionally, because the dietary information relies on self-reported 24-hour recall, it may not accurately reflect the eating patterns of all cancer survivors, so caution is needed in future analyses. To minimize errors, efforts were made to classify foods into tertiary food codes, assign conversion coefficients, and calculate avoidance rates. A PROC SUMMARY was created using the SAS program to quantify individual daily intake variables.

Data source

This study used 5-year raw data from 2016 to 2020 from KNHANES, a national health survey conducted annually by the Korea Disease Control and Prevention Agency with the prior consent of all participants. The survey includes health surveys and checkups conducted at mobile screening centers, and nutrition surveys conducted by personally visiting target households. In this study, raw data with personal information removed were provided and used after entering user information in the original data user security protocol and statistical data user compliance protocol on the KNHANES website. The Institutional Review Board (IRB) of the University of Ulsan approved this study (IRB number: 2023R0030).

Data analysis

Statistical analyzes were performed using the IBM Statistical Package for Social Sciences Software (version 28.0, IBM Corp., Armonk, NY, USA). A *P*-value of >0.05 was considered statistically significant. Demographic, health, and nutrition-related characteristics of cancer survivors were analyzed using complex sample descriptive statistics. Cross-tabulation analysis was used to determine differences in BMI according to participant characteristics, and Chi-square test and t-test statistical methods were used for group comparison. To analyze demographic, health-related, and nutritional-related factors affecting the BMI of cancer survivors, complex sample multivariate linear regression statistical method was used by entering independent variables showing significant results in each characteristic step by step.

Results

Cancer characteristics of cancer survivors

When cancer survivors were classified according to BMI, 1,654,179 (36.3%) were of normal weight, 1,509,602 (32.2%) were obese, 1,188,035 (26.7%) were overweight, and 201,850 (4.7%) were underweight.

Among the cancer types, 974,132 (21.4%) had others cancer, followed by 973,297 (21.3%) with thyroid cancers. 792,915 (17.4%) had stomach cancer, 597,037 (13.1%) with breast cancer, and 584,646 (12.8%) with cervical cancer. Excluding other cancers, stomach cancer was the most common in normal weight survivors (weighted $n=433{,}061$; 54.6%), whereas in obese, colon cancer (weighted $n=216{,}903$; 44.6%), thyroid cancer (weighted $n=411{,}326$; 42.3%), lung cancer (weighted $n=43{,}405$; 40.6%), and other cancers (weighted $n=369{,}461$; 37.9%) were the most common, and liver cancer was more common in overweight survivors (weighted $n=10{,}800$; 28.0%) than in obese survivors (weighted $n=8{,}808$; 22.8%) (Table 1).

Differences in BMI according to the demographic characteristics of cancer survivors

As a result of analyzing the BMI according to the demographic characteristics of cancer survivors, a significant difference was observed in terms of age ($t=142.51$, $p<.001$), gender ($x^2=5.35$, $p=.28$), marital status

Table 1 Cancer characteristics of the cancer survivors ($N=4{,}553{,}669$)

Variables	Categories	Total	Body mass index				95% CI	
			Underweight	Normal	Overweight	Obese		
		N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	Lower	Upper
Cancer type †	Stomach	792,915 (17.4)	72,090 (9.1)	433,061 (54.6)	165,815 (20.9)	121,949 (15.4)	644,972	921,998
	Thyroid	973,297 (21.3)	14,483 (1.4)	313,894 (32.3)	233,594 (24.0)	411,326 (42.3)	837,686	1,108,908
	Colon	486,211 (10.7)	21,570 (4.4)	98,811 (20.4)	148,927 (30.6)	216,903 (44.6)	393,668	578,752
	Breast	597,037 (13.1)	33,856 (5.6)	231,398 (38.8)	151,640 (25.4)	180,143 (30.2)	473,334	720,739
	Cervix	584,646 (12.8)	17,718 (3.0)	214,761 (36.7)	194,559 (33.3)	157,608 (27.0)	467,646	701,645
	Lung	106,794 (2.3)	0 (0)	33,390 (31.3)	29,999 (28.1)	43,405 (40.6)	75,848	137,739
	Liver	38,637 (0.9)	0 (0)	19,029 (49.2)	10,800 (28.0)	8,808 (22.8)	8,698	50,544
	Others	974,132 (21.4)	42,134 (4.3)	309,835 (31.9455)	252,702 (25.9)	369,461 (37.9)	822,502	1,114,744

† Possible duplicate answers

N = weighted sample size

($x^2 = 16.21$, $p < .001$), education level ($x^2 = 6.60$, $p = .20$), and economic activity ($x^2 = 12.18$, $p < .001$) (Table 2).

Differences in BMI according to the health-related characteristics of cancer survivors

Among the health-related characteristics of cancer survivors, significant differences in BMI were observed in terms of HTN ($x^2 = 41.16$, $p < .001$), sleep time ($t = 162.72$, $p < .001$), ECOG PS ($x^2 = 7.62$, $p = .008$), mental health counseling ($x^2 = 15.79$, $p < .001$), hemoglobin levels ($t = 280.32$, $p < .001$), and platelet ($t = 124.52$, $p < .001$), RBC ($t = 266.35$, $p < .001$), and WBC counts ($t = 112.18$, $p < .001$) (Table 3).

Differences in BMI according to the nutrition-related characteristics of cancer survivors

When differences in the BMI of cancer survivors were confirmed on the basis of nutrition-related characteristics, significant differences were noted in terms of the frequency of breakfast ($x^2 = 18.12$, $p = .010$) and lunch ($x^2 = 23.34$, $p < .001$) as well as energy ($t = 56.74$, $p < .001$), carbohydrate ($t = 72.46$, $p < .001$), protein ($t = 45.12$, $p < .001$), fat ($t = 34.03$, $p < .001$), fiber ($t = 51.13$, $p < .001$), sodium ($t = 40.33$, $p < .001$), vitamin D ($t = 21.77$, $p < .001$), and vitamin C ($t = 36.88$, $p < .001$) (Table 4).

Factors influencing the BMI of cancer survivors

Linear regression analysis revealed the following factors affecting the BMI of cancer survivors: for demographic characteristics, gender ($t = -4.07$, $p < .001$), marital status ($t = 4.20$, $p < .001$), and economic activity ($t = -3.27$, $p = .002$); for health-related characteristics, HTN ($t = 9.07$, $p < .001$), hemoglobin ($t = 5.29$, $p < .001$); and for nutrition-related characteristics, the frequency of breakfast ($t = -6.49$, $p < .001$) and sodium ($t = 2.41$, $p = .17$), vitamin D ($t = 3.02$, $p = .003$), and vitamin C ($t = -3.43$, $p = .001$) (Table 5).

Discussion

We here explored the factors affecting BMI in cancer survivors using national big data and observed significant factors in demographic characteristics (gender, marital status, and economic activity), health-related characteristics (HTN and hemoglobin levels), and nutrition-related characteristics (frequency of breakfast and sodium, vitamin D, and vitamin C intake). There are few studies using BMI to assess obesity status in cancer survivors, and few studies have examined demographic, health-related, and nutrition-related characteristics together as contributing factors. However, previous research indicates that demographic factors like office worker [21], lifestyle [22], and weight control interventions [23], as well as health factors such as blood sugar levels [24] and the hemoglobin-to-red cell distribution width ratio [25], and nutritional

Table 2 Differences in body mass index according to demographic characteristics of the cancer survivors ($N = 4,553,669$)

Variables	Categories	Total	Body mass index				95% CI		t or x^2	*p*
			Underweight	Normal	Overweight	Obese				
		M ± SD or *N* (%)	M ± SD or *N* (%)	M ± SD or *N* (%)	M ± SD or *N* (%)	M ± SD or *N* (%)	Lower	Upper		
Age (years)		61.52 ± 0.43	59.94 ± 1.70	60.43 ± 0.86	62.77 ± 0.62	61.93 ± 0.79	60.61	62.32	142.51	< 0.001
Gender	Male	1,631,412 (35.8)	66,050 (4.1)	556,463 (34.4)	384,857 (23.0)	624,042 (38.6)	1,397,395	1,839,042	5.35	0.028
	Female	2,922,257 (64.2)	135,801 (4.7)	1,097,716 (37.3)	803,179 (27.6)	885,561 (30.4)	2,572,305	3,250,685		
Marital status	Single	106,965 (2.3)	23,513 (22.0)	43,575 (40.7)	7,822 (7.3)	32,055 (30.0)	59,972	153,957	16.21	< 0.001
	Married	4,446,704 (97.7)	178,338 (4.0)	1,610,605 (36.2)	1,180,214 (26.5)	1,477,547 (33.2)	3,958,630	4,886,869		
Education level	≤ Middle school	1,698,963 (37.3)	109,427 (6.4)	555,590 (32.7)	464,342 (27.3)	569,604 (33.6)	1,479,400	1,878,386	6.60	0.020
	≥ High school	2,854,706 (62.7)	92,430 (3.3)	1,114,143 (39.0)	719,387 (25.2)	928,746 (32.5)	2,453,288	3,180,581		
Economic activity	Yes	2,124,991 (46.7)	58,227 (2.7)	688,205 (32.4)	597,217 (28.1)	781,342 (36.8)	1,862,797	2,386,995	12.18	< 0.001
	No	2,428,678 (53.3)	143,629 (5.9)	964,410 (39.7)	584,431 (24.1)	736,208 (30.3)	2,090,614	2,661,033		
Household size	Single	476,419 (10.5)	33,311 (7.0)	199,401 (41.9)	114,092 (23.9)	129,615 (27.2)	381,389	571,447	3.35	0.076
	≥ two	4,077,250 (89.5)	168,541 (4.1)	1,454,778 (35.7)	1,073,943 (26.3)	1,379,988 (33.9)	3,607,127	4,499,465		
Household income	Lower-than-median	2,223,565 (48.8)	134,116 (6.1)	820,480 (36.9)	529,924 (23.8)	739,045 (33.2)	1,948,597	2,443,604	5.93	0.062
	Higher-than-median	2,330,104 (51.2)	67,778 (2.9)	833,699 (35.8)	647,370 (27.8)	781,257 (33.5)	1,979,526	2,654,219		

N = weighted sample size, M = mean, SD = standard deviation

factors like the consumption of vegetables and fruits [26], can impact the survival rate and Obesity rate of cancer survivors.

The results of this study showed that females had a higher BMI than males. Previous studies reported that females had a higher risk factor for obesity level than males [27]. Therefore, a differentiated approach to obesity education programs according to the gender of cancer survivors is required.

Married cancer survivors had higher BMI than unmarried cancer survivors. Previous studies showed that marital status was significantly associated with obesity [28], and the risk factor for obesity measured by BMI were 1.7-fold higher in married individuals than in unmarried individuals [29], which was consistent with the results of this study. Marriage can lead to continuous weight gain for both couples while sharing meals in a social sense [28]. Therefore, developing a couple-based weight management program for cancer survivors for couples, not individuals, to improve eating habits and physical activities, which are common problems in the home, is required.

The economic activity of cancer survivors was a significant factor affecting BMI. Office workers are more likely to be obese owing to heavy work stress, high morning skipping rates, and lifestyle habits, such as drinking and smoking [21]. Moreover, cancer survivors have a higher rate of economic activity participation than cancer patients, spend more time working than engaging in leisure activities, and have less time for physical activity, resulting in a higher rate of obesity [30–32]. Therefore, weight loss is required by conducting a weight management program for cancer survivors who are actively engaged in economic activities owing to the risk of obesity due to heavy work and irregular eating habits.

In this study, the prevalence of hypertension in cancer survivors in the obese group was high at 44.0%, and hypertension was found to affect BMI. The prevalence of hypertension in cancer survivors is 70%, which is higher than that in the general population [33, 34] and is a major factor that increases cancer mortality by 20–30% [35, 36]. Therefore, it is necessary to recognize the risk of hypertension in cancer survivors and provide recommendations for controlling blood pressure in participants with a high rate of obesity.

The blood test results of the participants in this study showed that the higher the hemoglobin level, the higher the BMI, which is consistent with the results of previous studies [37]. Cancer survivors show changes in blood vessels' functional and structural characteristics owing to cancer treatment; therefore, determining participants' hematologic factors is essential. Among them, hemoglobin can reflect inflammatory conditions, including obesity, by evaluating reactive damage due to inflammation [38, 39]; Obesity is associated with a chronic systemic inflammatory state, which has a causal relationship with the development of insulin resistance, diabetes, and metabolic syndrome, and has been reported to increase hemoglobin levels compared to individuals of normal weight [37]. Moreover, hemoglobin is emerging as a new biomarker for predicting various clinical outcomes in various cancer survival [40]. High hemoglobin levels significantly affect the overall survival period of cancer survivors [24]; a decrease in hemoglobin levels can reduce obesity and cancer risk [5]. However, the possibility of an association between obesity and hemoglobin levels is suggested; however, evidence remains uncertain. Therefore, determining the mechanisms that cause fundamental abnormalities in cancer survivors by examining the relationship between obesity rates and various hematologic factors including hemoglobin levels in cancer survivors is needed.

Breakfast frequency in cancer survivors was associated with BMI, which was consistent with the results of previous studies that showed that eating breakfast reduced the risk of obesity [41, 42]. Low breakfast frequency increases the obesity rate [40] and further affects the survival rate of cancer survivors [21], so it is essential to encourage cancer survivors to eat breakfast.

High-sodium intake is associated with BMI, this finding was consistent with that of a study by Belle [43], which showed high-sodium intake in cancer survivors with obesity. In this study, the sodium intake of cancer survivors with obesity was 3179 mg, which was higher than the 1,500 mg intake recommended by the Dietary Approaches to Stop Hyperemia diet by the National Institutes of Health and the 2,400 mg intake recommended by the World Cancer Research Fund and American Institute for Cancer Research [44]. High sodium intake was found to be associated with obesity due to a mechanism that increases adipogenesis and adipose cytokines during sodium processing, or through a high-salt diet that enhances insulin-stimulated glucose absorption and adipogenic capacity. This has been shown to increase fat tissue [45]. Excessive sodium intake can negatively affect the health of cancer survivors. Therefore, intervention studies are required to evaluate the sodium intake of cancer survivors and establish dietary guidelines such that they can be appropriately consumed to prevent obesity.

Finally, the lower the vitamin c intake of cancer survivors, the higher the BMI. Furthermore, the results of previous studies [46] are consistent with those of the present study, showing an inverse proportion of vitamin C intake and BMI. Owing to its leptin inhibitory effect, vitamin C regulates adipocyte lipolysis, regulates glucocorticoid release from the adrenal glands, inhibits leptin secretion to adipocytes separated from glucose metabolism, improves hyperglycemia, reduces glycosylation, and

Table 3 Differences in body mass index according to health-related characteristics of the cancer survivors (*N* = 4,553,669)

Variables	Categories	Total	Body mass index				95% CI		t or x^2	*p*
			Underweight	Normal	Overweight	Obese				
		N (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	Lower	Upper		
DM	Yes	410,041 (7.4)	23,306 (7.2)	201,031 (40.4)	92,939 (27.1)	92,765 (25.3)	250,221	439,858	2.11	0.384
	No	4,143,628 (92.6)	221,458 (4.2)	1,441,947 (35.6)	1,113,864 (26.5)	1,366,359 (33.7)	3,611,861	4,494,899		
HTN	Yes	1,465,520 (32.2)	28,957 (2.0)	336,714 (23.0)	454,239 (31.0)	645,610 (44.0)	1,278,480	1,652,557	41.16	< 0.001
	No	3,088,149 (67.8)	172,894 (5.6)	1,317,466 (42.7)	733,796 (23.7)	863,993 (28.0)	2,721,949	3,454,350		
Sleep time (hours)		6.88 ± 0.04	6.99 ± 0.24	6.87 ± 0.06	6.83 ± 0.09	6.91 ± 0.07	6.80	6.97	162.72	< 0.001
Drinking	Yes	3,834,947 (84.2)	162,326 (4.0)	1,386,557 (36.3)	1,007,159 (26.2)	1,278,905 (33.5)	3,384,211	4,250,281	2.32	0.273
	No	718,722 (15.8)	49,525 (6.9)	267,639 (37.2)	173,499 (24.2)	228,059 (31.7)	609,779	827,611		
Smoking	Yes	1,520,003 (33.5)	55,210 (3.6)	543,049 (35.7)	391,824 (25.8)	529,920 (34.9)	1,296,365	1,742,229	1.01	0.601
	No	3,033,666 (66.5)	156,646 (4.9)	1,118,851 (36.9)	781,825 (25.8)	976,344 (32.4)	2,695,599	3,337,690		
Cancer screening	Yes	3,278,537 (72.0)	107,010 (3.3)	1,183,340 (36.1)	860,436 (26.2)	1,127,751 (34.4)	2,892,850	3,664,223	7.39	0.055
	No	1,275,132 (28.0)	94,843 (7.5)	470,839 (36.9)	327,599 (25.7)	381,851 (29.9)	1,097,173	1,453,090		
Subjective health status	Good	1,018,095 (22.4)	39,781 (3.9)	353,791 (34.8)	260,112 (25.5)	364,411 (35.8)	808,920	1,227,269	10.65	0.072
	Neutral	2,294,674 (50.4)	62,682 (2.7)	837,953 (36.5)	625,105 (27.2)	768,934 (33.6)	2,028,873	2,560,476		
	Bad	1,240,900 (27.2)	99,388 (8.0)	462,435 (37.3)	302,819 (24.4)	376,258 (30.3)	1,086,317	1,395,480		
ECOG PS	1	4,117,289 (90.4)	160,306 (3.9)	1,506,426 (36.6)	1,096,765 (26.6)	1,353,792 (32.9)	3,676,295	4,557,521	7.62	0.008
	2	436,380 (9.6)	45,545 (9.8)	148,054 (35.1)	76,890 (18.2)	165,891 (36.9)	334,647	510,097		
Physical activity level	Light	2,260,120 (49.6)	73,885 (5.1)	848,585 (37.5)	628,809 (26.0)	708,841 (31.4)	1,235,916	2,383,121	4.19	0.377
	Moderate	1,629,355 (35.8)	54,829 (3.6)	528,991 (34.5)	409,173 (26.9)	636,362 (35.0)	1,331,020	1,711,631		
	Vigorous	664,194 (14.6)	10,745 (1.6)	237,285 (35.7)	205,315 (30.9)	210,849 (31.8)	553,223	775,144		
Perceived stress level	High	1,083,313 (23.8)	77,458 (7.2)	414,215 (38.2)	247,172 (22.8)	344,668 (31.8)	941,604	1,224,006	5.38	0.050
	Low	3,470,156 (76.2)	124,401 (3.6)	1,245,684 (35.9)	929,476 (26.9)	1,170,595 (33.6)	3,061,921	3,844,351		
Mental health counseling	Yes	200,023 (4.4)	34,568 (17.3)	78,494 (39.2)	29,082 (14.6)	57,879 (28.9)	140,015	259,977	15.79	< 0.001
	No	4,353,646 (95.6)	167,303 (3.9)	1,587,686 (36.3)	1,146,566 (26.4)	1,452,091 (33.4)	3,872,192	4,799,699		
Hemoglobin (g/dL)		13.56 ± 0.05	12.48 ± 0.14	13.23 ± 0.07	13.69 ± 0.08	13.96 ± 0.08	13.46	13.66	280.32	< 0.001
Platelet (10^3/μL)		240.44 ± 1.93	233.75 ± 6.57	235.80 ± 3.29	244.48 ± 3.63	243.03 ± 3.00	236.73	244.40	124.52	< 0.001
RBC ($10^{\wedge 6}$/μL)		4.42 ± 0.02	4.28 ± 0.06	4.28 ± 0.02	4.48 ± 0.03	4.45 ± 0.03	4.39	4.45	266.35	< 0.001
WBC (10^3/μL)		5.79 ± 0.05	5.14 ± 0.22	5.62 ± 0.08	5.80 ± 0.10	6.04 ± 0.08	5.69	5.90	112.18	< 0.001

N = weighted sample size, M = mean, SD = standard deviation, DM = diabetes mellitus, HTN = hypertension, ECOG PS = Eastern Cooperative Oncology Group Performance Status, RBC = red blood cell, WBC = white blood cell

Table 4 Differences in body mass index according to nutrition-related characteristics of the cancer survivors (*N* = 4,553,669)

Variables	Categories	Total	Body mass index				95% CI		x^2 or t	*p*
			Underweight	Normal	Overweight	Obese				
		N (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	*N* (%) or M ± SD	Lower	Upper		
Diet	Yes	1,448,012 (28.7)	58,078 (5.1)	505,792 (35.3)	405,864 (26.6)	478,278 (33.0)	951,822	1,544,036	0.10	0.973
	No	3,105,657 (71.3)	136,778 (4.8)	1,129,296 (35.7)	843,561 (27.4)	996,022 (32.1)	2,544,816	3,169,498		
Dietary supplements	Yes	2,841,113 (62.4)	116,785 (4.1)	1,072,249 (37.7)	751,761 (26.5)	900,318 (31.7)	2,171,066	3,049,157	2.42	0.312
	No	1,612,556 (37.6)	77,569 (5.1)	557,148 (32.2)	479,857 (29.9)	497,982 (32.8)	1,328,981	1,690,843		
Nutrition education	Yes	767,906 (5.8)	18,448 (2.4)	588,177 (76.6)	48,456 (6.3)	112,825 (14.7)	175,352	794,372	1.70	0.443
	No	3,785,763 (94.2)	175,906 (4.6)	1,340,577 (35.4)	1,054,205 (27.9)	1,215,075 (32.1)	3,353,968	4,216,355		
Frequency of breakfast (per week)	5 ~ 7	3,252,696 (71.4)	161,656 (5.0)	1,240,209 (38.1)	869,139 (26.7)	981,692 (30.2)	2,872,280	3,633,111	18.12	0.010
	3 ~ 4	532,146 (11.7)	11,848 (2.2)	164,888 (31.0)	181,675 (34.2)	173,735 (32.6)	145,054	589,151		
	1 ~ 2	341,588 (7.5)	20,854 (6.1)	117,772 (34.5)	56,594 (16.6)	146,368 (42.8)	169,676	372,298		
	Seldom	427,239 (9.4)	0 (0)	55,883 (17.0)	145,210 (29.2)	236,146 (53.8)	235,461	433,016		
Frequency of lunch (per week)	5 ~ 7	4,192,572 (92.1)	269,804 (4.6)	1,551,883 (36.6)	1,053,765 (25.8)	1,317,120 (33.0)	3,256,234	4,208,908	23.34	< 0.001
	3 ~ 4	185,690 (4.0)	10,194 (6.7)	38,242 (25.0)	96,508 (43.6)	40,746 (24.7)	105,566	199,814		
	1 ~ 2	54,030 (1.2)	14,356 (26.9)	7,630 (14.2)	23,212 (43.5)	8,832 (15.4)	35,200	71,576		
	Seldom	121,377 (2.7)	0 (0)	31,039 (25.6)	59,133 (48.7)	31,205 (25.7)	94,018	148,728		
Frequency of dinner (per week)	5 ~ 7	3,821,995 (83.9)	190,001 (5.0)	1,360,701 (35.6)	1,037,109 (27.1)	1,234,184 (32.3)	3,346,160	4,237,827	6.61	0.351
	3 ~ 4	435,594 (9.6)	0 (0)	166,558 (38.2)	128,168 (29.4)	140,868 (32.4)	87,089	478,099		
	1 ~ 2	147,714 (3.2)	0 (0)	7,737 (5.2)	71,820 (48.6)	68,157 (46.1)	14,997	179,231		
	Seldom	148,366 (3.3)	4,357 (3.0)	23,757 (16.0)	66,161 (44.6)	54,091 (36.4)	15,997	180,645		
Energy (kcal)		1754.17 ± 30.92	1491.54 ± 123.21	1730.84 ± 31.69	1750.67 ± 42.34	1882.34 ± 64.98	1693.11	1815.22	56.74	< 0.001
Carbohydrate (g)		281.72 ± 3.89	263.04 ± 24.47	282.11 ± 4.85	276.60 ± 5.76	288.47 ± 6.46	274.05	289.40	72.46	< 0.001
Protein (g)		60.96 ± 1.35	47.43 ± 4.01	59.87 ± 1.23	61.77 ± 1.91	63.50 ± 2.96	58.29	63.63	45.12	< 0.001
Fat (g)		35.35 ± 1.04	26.57 ± 2.58	35.17 ± 1.50	36.64 ± 1.46	35.76 ± 2.16	33.30	37.39	34.03	< 0.001
Fiber (g)		27.67 ± 0.54	21.99 ± 0.51	29.48 ± 0.93	26.56 ± 0.66	27.48 ± 0.79	26.61	28.74	51.13	< 0.001
Sodium (g)		2976.58 ± 73.81	2048.69 ± 196.07	2916.78 ± 52.87	2979.73 ± 98.30	3179.23 ± 166.83	2830.81	3122.34	40.33	< 0.001
Vitamin D (mg)		3.07 ± 0.14	2.09 ± 0.32	2.57 ± 0.15	3.34 ± 0.33	3.54 ± 0.30	2.80	3.35	21.77	< 0.001
Vitamin C (mg)		64.41 ± 1.75	53.59 ± 4.99	78.44 ± 3.65	56.51 ±1 0.98	57.26 ± 0.07	60.96	67.85	36.88	< 0.001

N = weighted sample size, M = mean, SD = standard deviation

Table 5 Factors influencing body mass index of the cancer survivors (*N* = 4,553,669)

Variables	Categories	Body mass index				
		B	95% CI		*t*	*p*
			Lower	Upper		
Demographic characteristics						
Age (years)		0.02	-0.01	0.09	0.54	0.588
Gender	Male (Ref: female)	-0.30	-0.44	-0.15	-4.07	< 0.001
Marital status	Married (Ref: single)	0.61	0.32	0.89	4.20	< 0.001
Educational level	≤ Middle school (Ref: high school)	0.11	-0.06	0.28	1.30	0.186
Economic activity	No (Ref: yes)	-0.17	-0.28	-0.17	-3.27	0.002
Health-related characteristics						
HTN	Yes (Ref: no)	0.49	0.39	0.60	9.07	< 0.001
Sleep time (hours)		−0.11	-0.05	0.03	−0.55	0.577
ECOG PS	2 (Ref: 1)	0.04	-0.18	0.24	0.41	0.685
Mental health counseling	Yes (Ref: no)	−0.02	-0.27	0.23	−0.16	0.870
Hemoglobin (g/dL)		0.13	0.08	0.18	5.29	< 0.001
Platelet (10^3/μL)		0.01	-3.20	0.02	1.92	0.057
RBC (10^6/μL)		0.11	-0.08	0.30	1.11	0.269
WBC (10^3/μL)		0.03	-0.04	0.05	0.15	0.882
Nutrition-related characteristics						
Frequency of breakfast (per week)		−0.15	-0.19	-0.11	−6.49	< 0.001
Frequency of lunch (per week)		−0.06	-0.13	0.02	−1.53	0.140
Energy (kcal)		0.01	0.00	0.01	1.11	0.267
Carbohydrate (g)		0.01	-0.01	0.01	−0.42	0.678
Protein (g)		−0.01	-0.04	0.01	−1.05	0.296
Fat (g)		−0.02	-0.05	0.01	−1.11	0.271
Fiber (g)		0.01	-0.04	0.01	0.17	0.868
Sodium (g)		5.17	-9.37	9.39	2.41	0.017
Vitamin D (mg)		0.01	0.00	0.15	3.02	0.003
Vitamin C (mg)		−0.01	-0.04	0.05	−3.43	0.001
		$R^2 = 0.20$				

N = weighted sample size, M = mean, SD = standard deviation, Ref = Reference, HTN = hypertension, ECOG PS = Eastern Cooperative Oncology Group Performance Status, RBC = red blood cell, WBC = white blood cell

increases immune response to infection [47], thereby significantly affecting obesity reduction [48, 49]. Additionally, vitamin C controls the mRNA expression of tumor factors [50], thereby decreasing the risk of death by 24% among cancer survivors [51] and reducing cancer formation [52]. In contrast, some studies have argued that vitamin C and BMI are not related [51], and no difference in cancer survival rates is observed [48]. As such, research results on vitamin C intake, obesity rate, and cancer survival rates are contradictory; therefore, attention should be paid to interpreting the results.

This study has some limitations. First, calculating obesity was based on BMI; however, differences may exist in the comparison of results with studies that use various variables, such as waist and abdominal circumference. Reliance on BMI as an indicator of obesity, which is the most used anthropometric measure in clinical and epidemiological studies, including this one, may be inherently limiting. BMI does not distinguish between body fat and lean tissue mass, nor does it provide information on the amount or location of body fat. Many factors, including body fat distribution and low skeletal muscle mass, likely contribute to obesity in cancer survivors, and single measurements are insufficient to capture these complexities. More studies using a variety of obesity measurement tools are needed to better understand the complex interactions between obesity and its causes in different cancer survivor populations. Second, errors can occur owing to secondary data that rely on self-report. Third, there may be limitations in accurate measurement using dietary intake data using the 24-h recall method; therefore, external validity may be insufficient because long-term eating habits of cancer survivors cannot be considered. Fourth, there may be limitations in generalizing it by expanding the results of this study to all cancer survivors, targeting only cancer survivors who participated in some health surveys. Therefore, further studies that accurately measure obesity and dietary intake are needed in the future. However, despite these limitations, this study is meaningful in that it divided the degree of obesity in cancer survivors using BMI and identified health-related characteristics.

The study highlights the importance of identifying lifestyle factors that influence BMI in cancer survivors. Providing appropriate counseling and interventions is crucial for managing obesity rate and improving their quality of life. Various policies and programs can help generate knowledge about effective behavioral and treatment changes, supporting cancer survivors in maintaining healthy lifestyles. Implementing educational programs by experts throughout all stages of cancer treatment can equip survivors with essential knowledge about lifestyle and nutrition, helping them achieve a healthier quality of life. Therefore, confirming the impact of various factors of cancer survivors on BMI through repeated studies and developing guidelines and customized intervention programs for preventing obesity in cancer survivors based on the results of these repeated studies are necessary. This allows the development of mechanisms to shift from individual-level interventions to broad and systematic approaches within the entire healthcare system.

Conclusions

Important factors affecting BMI in cancer survivors include demographic characteristics (gender, marital status, economic activity), health-related characteristics (HTN, hemoglobin levels), and nutrition-related characteristics (frequency of breakfast, vitamin D and vitamin C levels). Based on these results, managing obesity in cancer survivors requires screening those at risk for obesity after cancer diagnosis, assessing health needs and risk factors, and changing health behaviors and eating habits. This also suggests the need for interventions to prevent and manage obesity as a health promotion strategy for cancer survivors. Cancer survivors have difficulty accessing reliable information online, and most prefer to receive information about diet, weight management, and physical activity from their health care providers [53]. Therefore, health professionals can have a positive impact by identifying obesity risk factors and providing accurate and consistent information to prevent obesity in cancer survivors and further lead healthy lives during cancer survivorship. Future research is needed to develop tools that can detect and manage obesity in cancer survivors early and to provide an identical database through repeated studies on health characteristics that affect obesity. The data of this study comprehensively identified factors related to BMI of cancer survivors from various aspects, and based on the research results, it shows the will to prevent BMI increase of cancer survivors and further manage obesity of cancer survivors. To reduce the obesity rate and increase the survival rate of cancer survivors, it is necessary to identify various factors and establish personalized health promotion strategies and develop health intervention programs.

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Author contributions
IH Ku: Conceptualization, Investigation, Data curation, Formal analysis, Writing-Original draft preparation; S Ko: Conceptualization, Methodology, Supervision, Interpretation of data, Writing- Reviewing and Editing, Project administration. All authors have read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The raw data, with personal information removed, were accessed and used in accordance with the original data user security protocol and statistical data user compliance protocol available on the KNHANES website. Data collection for the survey is voluntary, with prior consent obtained from all participants. For this secondary study, the authors obtained IRB approval in the Ulsan University (IRB No. 2023R0030).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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