



Research Article

# Self-reported weight change and diet quality in relation to metabolic syndrome among Korean cancer survivors: a cross-sectional study using the Korea National Health and Nutrition Examination Survey 2019–2021

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**Objectives:** Using data from the 2019–2021 Korea National Health and Nutrition Examination Survey, we examined the association between dietary quality and metabolic syndrome by self-reported weight change among adult Korean cancer survivors.

**Methods:** We analyzed 340 cancer survivors ( $\geq 5$  years post-diagnosis) by one-year weight change (stable, loss, and gain). Dietary quality was assessed using the Korean Healthy Eating Index (KHEI), and metabolic syndrome was defined according to standard criteria. Relative risks (RR) were estimated using a modified Poisson regression.

**Results:** The weight loss group was older than the weight gain group ( $P < 0.001$ ). Females were more prevalent in the loss and gain than in the maintenance group ( $P = 0.008$ ). Hypertension prevalence was highest in the loss and lowest in the gain group ( $P = 0.028$ ); other risk factors were similar. The gain group had the highest body mass index ( $P = 0.011$ ). KHEI scores were highest in the maintenance ( $66.59 \pm 0.76$ ) and lowest in the gain group ( $60.42 \pm 1.77$ ;  $P = 0.006$ ), with significantly lower whole grain ( $P = 0.036$ ) and fruit intake ( $P = 0.014$ ). Compared with the maintenance group, the gain group demonstrated higher risks of metabolic syndrome (RR: 2.07, 95% confidence interval [CI]: 1.40–3.06;  $P < 0.001$ ), abdominal obesity (RR: 1.93, 95% CI: 1.36–2.74;  $P < 0.001$ ), and impaired fasting glucose (RR: 1.70, 95% CI: 1.23–2.34;  $P < 0.01$ ). Within the gain group, participants in the lowest KHEI quartile had increased risks of metabolic syndrome (RR: 2.81, 95% CI: 1.06–7.43;  $P < 0.05$ ) and hypertriglyceridemia (RR: 7.29, 95% CI: 1.54–34.61;  $P < 0.05$ ).

**Conclusion:** Accordingly, weight change and dietary quality may critically affect the metabolic health of cancer survivors. Lifestyle management, including weight control and tailored diets, may help prevent metabolic disorders and support long-term health.

**Keywords:** cancer survivors; body weight changes; diet, healthy; metabolic syndrome; nutrition surveys

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## INTRODUCTION

Cancer survivors are generally defined as individuals living more than five years after a cancer diagnosis [1]. The term encompasses both those currently living with

cancer and those considered cured, representing a broad concept that extends from the time of diagnosis throughout the lifespan [2]. Given the recent advances in early detection and treatment, the number of cancer survivors has steadily increased, and issues related to post-treatment health management and quality of life have become major concerns in the field of healthcare [3].

During treatment, cancer survivors may experience both weight loss and weight gain, and these changes have clinical implications beyond simple variations in body weight [4]. Rapid weight loss due to cancer cachexia or malnutrition commonly occurs during treatment, and moderate weight recovery subsequently contributes to the maintenance of physiological function and improving prognosis [5, 6]. Conversely, long-term studies have reported that excessive post-treatment weight gain increases the risk of abdominal obesity, insulin resistance, metabolic syndrome, and even mortality [7, 8]. Accordingly, the timing and degree of weight change can lead to markedly different health outcomes.

Sarcopenic obesity, characterized by the coexistence of sarcopenia and abdominal obesity, is highly prevalent among patients with cancer and is associated with poor treatment response, impaired metabolic function, and reduced survival [9, 10]. Among Korean cancer survivors, sarcopenia is reportedly associated with an increased risk of metabolic syndrome [11], underscoring the importance of managing body composition, particularly the balance between muscle and fat mass, rather than focusing solely on weight changes.

Metabolic syndrome, which includes abdominal obesity, hypertension, hyperglycemia, and dyslipidemia, is a known risk factor for cardiovascular disease and cancer recurrence [12]. Notably, cancer survivors with metabolic syndrome have a higher risk of cardiovascular disease, emphasizing the importance of ongoing metabolic health management, even after completion of cancer treatment [13].

Dietary quality plays a key role in regulating metabolic health. The Korean Healthy Eating Index (KHEI), a validated tool developed to assess dietary quality in Korean adults, has been widely used in national nutrition surveys [14]. For example, higher dietary quality was found to be associated with a lower risk of metabolic syndrome and chronic diseases, primarily through

mechanisms such as reduced inflammation and improved insulin sensitivity [15]. Moreover, dietary quality may indirectly influence metabolic health by affecting weight and body composition, making it an essential component of survivorship care.

However, few studies have examined the interplay between weight-change patterns, dietary quality, and metabolic syndrome risk in Korean cancer survivors. In the current study, we utilized data from the Korea National Health and Nutrition Examination Survey (KNHANES) to classify cancer survivors according to self-reported weight changes during the past year and compared their KHEI scores and the prevalence of metabolic syndrome. Additionally, we analyzed the association between dietary quality and risk of metabolic syndrome according to weight-change status to provide evidence for developing tailored nutritional management strategies for cancer survivors.

## METHODS

### Ethics statement

The 2019–2021 KNHANES was conducted with approval from the Research Ethics Review Committee of the Korea Centers for Disease Control and Prevention (KCDC) (IRB approval numbers: 2018-01-03-C-A, 2018-01-03-2C-A, 2018-01-03-5C-A). All participants provided informed consent.

### 1. Study design

This cross-sectional study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) Guidelines for observational research [16].

### 2. Study population

We used data from the 2019 to 2021 cycles of the 8th KNHANES, which included the variables required to calculate the KHEI. A total of 15,549 adults aged  $\geq 19$  years participated in the survey. Among them, 2,552 individuals reported having been diagnosed with cancer by a physician, and 287 who had survived  $> 5$  years post-diagnosis were classified as cancer survivors [11] and selected for the primary analysis. Cancer types included stomach, liver, colorectal, breast, cervical, lung, and thyroid. Our study included only those who had survived for  $> 5$  years to minimize acute-phase effects

immediately after treatment and to better reflect stable health behaviors and dietary quality.

Participants were excluded if they reported implausible energy intake (< 500 kcal or > 5,000 kcal;  $n = 9$ ), had missing anthropometric or biochemical data ( $n = 144$ ), or lacked key demographic data ( $n = 2$ ). Ultimately, 340 participants (125 males and 215 females) were included in the final analysis.

### 3. Variables and measurements

#### 1) General characteristics

Sociodemographic variables included age, sex, household income, educational level, residential area, smoking status, alcohol consumption, and physical activity level. Incomes were categorized into quartiles (low, middle-low, middle-high, and high). Education level was classified as elementary school, middle school, high school, college, or higher. Residential area was defined as urban (“dong”) or rural (“eup/myeon”) based on administrative districts.

Current smoking status and alcohol consumption ( $\geq 1$  drink/month in the past year) were also assessed. Physical activity was classified as ‘active’ if participants engaged in  $\geq 2$  hours 30 minutes of moderate-intensity activity per week,  $\geq 1$  hour 15 minutes of high-intensity activity, or an equivalent combination. At this point, 1 minute of high-intensity light was converted to 2 minutes of moderate-intensity light.

#### 2) Weight change

Weight-change status was classified based on the question, “Has there been any change in your body weight compared to that 1 year ago?” “No change” (including increase and decrease of < 3 kg) was classified as the weight maintenance group ( $n = 235$ ); “weight decreased” ( $\geq 3$  kg) as the weight loss group ( $n = 36$ ), and “weight increased” ( $\geq 3$  kg) as the weight gain group ( $n = 69$ ). Additionally, the amount of weight change over one year was classified into three categories: 3–5.9 kg; 6–9.9 kg; and  $\geq 10$  kg. Weight control efforts over one year were classified as “weight loss effort,” “weight maintenance effort,” “weight gain effort,” and “no effort.”

#### 3) Metabolic indicators

Metabolic variables included waist circumference;

systolic and diastolic blood pressure; and fasting blood glucose, triglyceride, and high-density lipoprotein cholesterol (HDL-C) levels. Metabolic syndrome was defined using the National Cholesterol Education Program Adult Treatment Panel III and Korean Society for the Study of Obesity criteria [12, 17].

Diagnostic criteria were as follows: abdominal obesity (waist circumference  $\geq 90$  cm for males and  $\geq 85$  cm for females); elevated blood pressure (systolic  $\geq 130$  mmHg or diastolic  $\geq 85$  mmHg); impaired fasting glucose (fasting blood glucose  $\geq 100$  mg/dL); hypertriglyceridemia (triglycerides  $\geq 150$  mg/dL); and low HDL-C (< 40 mg/dL for males and < 50 mg/dL for females). Metabolic syndrome was diagnosed when  $\geq 3$  of the five criteria were met.

Body mass index (BMI) was calculated by dividing weight (kg) by height ( $m^2$ ) and was classified as follows: underweight, < 18.5 kg/ $m^2$ ; normal, 18.5–22.9 kg/ $m^2$ ; overweight, 23.0–24.9 kg/ $m^2$ ; and obese,  $\geq 25.0$  kg/ $m^2$ .

#### 4) Dietary intake and quality

Dietary intake data were collected via a 24-hour recall. Total energy and macronutrient intake were calculated, and the energy percentages of carbohydrates, proteins, and fats were derived.

Dietary quality was assessed using KHEI. The KHEI comprises 14 items divided into three evaluation domains. The first domain, “adequacy,” evaluates whether recommended food groups and nutrients are sufficiently consumed, including consumption of breakfast, mixed grains, fruits (total and fresh fruits), vegetables (excluding *kimchi* and pickled vegetables), meat/fish/eggs/beans, and milk and dairy products. The second domain, “moderation,” assesses components that should be limited, including the percentage of energy from saturated fatty acids, sodium intake, and the percentage of energy intake from sugars and beverages. The third domain, “balance,” focuses on the composition of energy intake and evaluates the balance of the percentage of energy from carbohydrates and fats and total energy intake. Each item was scored according to the standards, and the total score was calculated from 100 points. Scoring criteria and calculation methods were based on the official guidelines of the KCDC [18].

#### 4. Statistical analysis

Data analyses were performed using SAS 9.4 (SAS Institute), accounting for the KNHANES complex sampling (stratification, clustering, and weighting). Categorical variables are expressed as frequencies (weighted %), and continuous variables as means  $\pm$  standard errors.

Differences in metabolic disease indicators and KHEI scores among the three groups (weight maintenance, weight loss, and weight gain) according to self-reported weight changes over the recent 1 year were compared using the chi-square test and regression analysis. Given the high prevalence of metabolic syndrome in the study population, the odds ratio was judged to be inappropriate owing to the possibility of overestimation, and a modified Poisson regression model with robust standard errors was used to estimate the relative risk (RR) [19]. To analyze the association between weight-change status and metabolic syndrome and its components, dependent variables were set as the presence or absence (binary) of metabolic syndrome and each metabolism-related disease (abdominal obesity, hypertriglyceridemia, low HDL-C, impaired fasting glucose, and elevated blood pressure). The main independent variable was the weight-change type, and RR was calculated using the weight maintenance group as the reference group. Model 1 included age and sex as covariates, with Model 2 additionally including residential area and total energy intake. To analyze the association between the total KHEI score and metabolic syndrome and its components, the KHEI was divided into quartiles (Q1-Q4), with Q4 (the group with the highest dietary quality) as the reference. Analysis was stratified according to weight-change status (weight maintenance, loss, and gain). Results are presented as RRs and 95% confidence intervals (CIs), and the statistical significance was set at  $P < 0.05$ .

## RESULTS

### 1. General characteristics

Table 1 summarizes the general characteristics of participants according to their weight-change status over the previous year. Age differed significantly among groups ( $P < 0.001$ ): the weight loss group was the oldest ( $68.32 \pm 1.95$  years), followed by the weight maintenance group

( $61.66 \pm 1.00$  years), and the weight gain group was the youngest ( $52.25 \pm 1.85$  years). Females accounted for a higher proportion in the weight loss (71.80%) and weight gain (80.14%) groups than in the weight maintenance group (58.17%) ( $P = 0.008$ ). The proportion of rural residents was highest in the weight loss group (31.18%) and lowest in the weight gain group (6.74%) ( $P = 0.014$ ). Other variables, including household income, education level, alcohol consumption, smoking, physical activity, and weight control efforts, did not differ significantly between the groups.

BMI was significantly higher in the weight gain group ( $24.95 \pm 0.49$  kg/m<sup>2</sup>) than in the weight maintenance ( $23.68 \pm 0.24$  kg/m<sup>2</sup>) and weight loss ( $22.71 \pm 0.57$  kg/m<sup>2</sup>) groups ( $P = 0.011$ ). The weight loss group had the highest proportion of normal-weight (46.46%) and underweight (5.97%) individuals, whereas the weight gain group had the highest proportion of obese (53.16%) individuals. Regarding the magnitude of weight change, 68.45% of the weight loss group lost 3–6 kg over the previous year, while 81.39% of the weight gain group gained 3–6 kg during the same period. Weight control efforts did not differ significantly between groups.

### 2. Prevalence of metabolic syndrome and its components

Table 2 presents the prevalence of metabolic syndrome and its components according to weight-change status over the past year. Among the components, elevated blood pressure was most prevalent in the weight loss group (52.29%) and least prevalent in the weight gain group (26.25%), with significant group differences ( $P = 0.028$ ). In contrast, the prevalence of overall metabolic syndrome, abdominal obesity, hypertriglyceridemia, low HDL-C, and impaired fasting glucose did not differ significantly between groups.

### 3. Dietary intake and dietary quality assessment

Table 3 presents the dietary intake and KHEI scores according to weight-change status over the previous year. Total energy intake and macronutrient energy ratios (carbohydrates, proteins, and fats) did not differ significantly between groups. The total KHEI score was highest in the weight maintenance group ( $66.59 \pm 0.76$ ) and lowest in the weight gain group ( $60.42 \pm 1.77$ ) ( $P = 0.006$ ).

**Table 1.** General characteristics of cancer survivors according to weight change

Variables	Weight maintenance (n = 235)	Weight loss (n = 36)	Weight gain (n = 69)	P-value
Age (year)	61.66 ± 1.00 <sup>b</sup>	68.32 ± 1.95 <sup>a</sup>	52.25 ± 1.85 <sup>c</sup>	< 0.001
Time since cancer diagnosis (year)	12.35 ± 0.48	10.86 ± 1.01	11.84 ± 0.67	0.385
Sex				0.008
Male	101 (41.83)	11 (28.20)	13 (19.86)	
Female	134 (58.17)	25 (71.80)	56 (80.14)	
Marital status				N/A
Married	233 (98.83)	36 (100)	65 (90.20)	
Single	2 (1.17)	0 (0.00)	4 (9.80)	
Region				0.014
Urban	173 (80.31)	25 (68.82)	59 (93.26)	
Rural	62 (19.69)	11 (31.18)	10 (6.74)	
Household income				0.506
Low	74 (23.49)	16 (35.90)	19 (19.86)	
Middle-low	54 (23.23)	10 (26.81)	15 (23.90)	
Middle-high	53 (24.00)	5 (16.91)	21 (33.04)	
High	54 (29.27)	5 (20.38)	14 (23.21)	
Education level				0.426
≤ Elementary school	71 (23.74)	17 (33.71)	18 (16.85)	
Middle school	30 (10.66)	6 (18.91)	9 (16.44)	
High school	74 (34.71)	7 (22.45)	22 (29.94)	
≥ College	60 (30.89)	6 (24.93)	20 (36.76)	
Smoking				0.456
Non-smoker	217 (91.24)	29 (82.87)	61 (90.12)	
Current smoker	18 (8.76)	7 (17.13)	8 (9.88)	
Alcohol drinking				0.312
Non drinker	145 (57.16)	24 (63.52)	39 (46.98)	
Drinker	90 (42.84)	12 (36.48)	30 (53.02)	
Physical activity				0.809
Passive	146 (60.33)	26 (66.79)	41 (62.27)	
Active	89 (39.67)	10 (33.21)	28 (37.73)	
BMI (kg/m <sup>2</sup> )				0.011
Obesity degree	23.68 ± 0.24 <sup>bc</sup>	22.71 ± 0.57 <sup>c</sup>	24.95 ± 0.49 <sup>a</sup>	N/A
Underweight (< 18.5)	10 (3.82)	2 (5.97)	0 (N/A)	
Normal (18.5–22.9)	100 (42.27)	20 (46.46)	17 (31.63)	
Overweight (23–24.9)	50 (20.58)	7 (27.27)	15 (15.22)	
Obese (≥ 25)	75 (33.34)	7 (20.31)	37 (53.16)	
Range of weight change during the past year (kg) <sup>1)</sup>				N/A
< 3	235 (100.0)	-	-	
3–5.9	-	27 (68.45)	59 (81.39)	
6–9.9	-	6 (24.66)	8 (13.75)	
≥ 10	-	3 (6.89)	2 (4.86)	
Weight control efforts during the past year				0.052
Weight loss effort	67 (30.68)	11 (37.76)	35 (47.90)	
Weight maintenance effort	60 (26.24)	4 (10.15)	15 (20.00)	
Weight gain effort	17 (6.80)	7 (20.05)	1 (2.38)	
No weight control effort	91 (36.28)	14 (32.04)	18 (29.72)	

n (weighted %) or Mean ± SE.

P-values were calculated using the general linear model for continuous variables and the  $\chi^2$  test for categorical variables in complex sample survey data analysis.

BMI, body mass index; N/A, not applicable.

<sup>1)</sup>Range of weight change was presented as absolute values.

<sup>a-c</sup>Values with different superscript letters differ significantly ( $P < 0.05$ , Scheffé's test).

**Table 2.** Prevalence of metabolic syndrome and metabolic indicators by weight change group

Variables	Weight maintenance (n = 235)	Weight loss (n = 36)	Weight gain (n = 69)	P-value
Metabolic syndrome	72 (26.83)	13 (37.46)	30 (35.91)	0.283
Abdominal obesity	91 (36.88)	10 (30.47)	40 (51.84)	0.119
High triglyceride	53 (24.27)	8 (24.98)	20 (27.42)	0.897
Low HDL-C	73 (25.54)	18 (42.73)	24 (36.32)	0.096
Hyper blood glucose	106 (41.19)	17 (48.62)	36 (49.70)	0.439
High blood pressure	108 (42.47)	20 (52.29)	24 (26.25)	0.028

n (weighted %).

HDL-C, high-density lipoprotein cholesterol.

P-values were calculated using the  $\chi^2$  test for categorical variables in complex sample survey data analysis.

**Table 3.** Korean Healthy Eating Index scores of cancer survivors by weight change group

Variables	Weight maintenance (n = 235)	Weight loss (n = 36)	Weight gain (n = 69)	P-value
Energy (kcal)	1,778.77 ± 56.73	1,856.50 ± 153.37	1,649.31 ± 84.07	0.350
% energy of carbohydrate	66.87 ± 0.77	66.70 ± 2.06	65.88 ± 1.59	0.854
% energy of protein	14.56 ± 0.32	15.73 ± 1.07	14.57 ± 0.59	0.576
% energy of fat	18.57 ± 0.59	17.58 ± 1.36	19.54 ± 1.27	0.571
Total KHEI score (0–100)	66.59 ± 0.76 <sup>a</sup>	65.19 ± 2.07 <sup>ab</sup>	60.42 ± 1.77 <sup>b</sup>	0.006
Component of the KHEI score				
Adequacy	34.62 ± 0.68 <sup>a</sup>	33.65 ± 2.03 <sup>ab</sup>	29.94 ± 1.54 <sup>b</sup>	0.020
Have breakfast (0–10)	8.79 ± 0.23	9.11 ± 0.35	8.11 ± 0.70	0.440
Mixed grain intake (0–5)	2.26 ± 0.17 <sup>a</sup>	2.61 ± 0.44 <sup>a</sup>	1.53 ± 0.26 <sup>b</sup>	0.036
Total fruit intake (0–5)	3.12 ± 0.16 <sup>a</sup>	2.66 ± 0.45 <sup>ab</sup>	2.11 ± 0.30 <sup>b</sup>	0.014
Fresh fruit intake (0–5)	3.26 ± 0.17	2.91 ± 0.47	2.53 ± 0.35	0.177
Total vegetable intake (0–5)	3.72 ± 0.10	3.94 ± 0.25	3.37 ± 0.18	0.118
Vegetable intake, excluding Kimchi and pickled vegetables intake (0–5)	3.39 ± 0.13	3.43 ± 0.24	3.17 ± 0.21	0.597
Meat, fish, eggs, and bean intake (0–10)	7.11 ± 0.23	6.99 ± 0.55	6.48 ± 0.46	0.432
Milk and milk product intake (0–10)	2.96 ± 0.34	2.00 ± 0.82	2.65 ± 0.54	0.560
Moderation	22.33 ± 0.42	22.43 ± 1.05	21.72 ± 0.89	0.824
Sodium intake (0–10)	7.50 ± 0.20	7.10 ± 0.58	8.14 ± 0.37	0.221
Percentage of energy from saturated fatty acid (0–10)	8.61 ± 0.21	8.53 ± 0.56	7.31 ± 0.60	0.124
Percentage of energy from sweets and beverages (0–10)	6.22 ± 0.30	6.81 ± 0.77	6.26 ± 0.62	0.787
Energy balance	9.64 ± 0.35	9.11 ± 0.89	8.76 ± 0.68	0.449
Percentage of energy from carbohydrate (0–5)	2.73 ± 0.15	2.44 ± 0.40	2.39 ± 0.30	0.556
Percentage of energy intake from fat (0–5)	3.66 ± 0.15	3.55 ± 0.36	3.15 ± 0.31	0.310
Energy intake (0–5)	3.25 ± 0.17	3.12 ± 0.50	3.21 ± 0.35	0.966

Mean ± SE.

Adjusted for age and sex.

P-values were calculated using a general linear model for continuous variables in the complex sample survey data analysis.

KHEI, Korean Healthy Eating Index.

<sup>a-c</sup>Means with different superscript letters indicate significant differences among groups ( $P < 0.05$ ) based on Scheffé's post hoc test.

Similarly, the adequacy domain score was highest in the weight maintenance group ( $34.62 \pm 0.68$ ) and lowest in the weight gain group ( $29.94 \pm 1.54$ ) ( $P = 0.020$ ).

For specific items, the mixed grain intake score was significantly lower in the weight gain group ( $1.53 \pm 0.26$ ) than in the weight loss ( $2.61 \pm 0.44$ ) and weight mainte-

nance ( $2.26 \pm 0.17$ ) groups ( $P = 0.036$ ). Furthermore, the total fruit intake score was highest in the weight maintenance group ( $3.12 \pm 0.16$ ) and lowest in the weight gain group ( $2.11 \pm 0.30$ ) ( $P = 0.014$ ). No significant group differences were observed in moderation or balance domain scores.

#### 4. Relative risk for metabolic syndrome and its components by weight change

Table 4 summarizes the RRs of metabolic syndrome and its components by weight-change status over the previous year. The weight gain group had a significantly higher risk of metabolic syndrome than the weight maintenance group. The RR was 1.98 (95% CI: 1.34–2.93) in Model 1 (adjusted for age and sex) and 2.07 (95% CI: 1.40–3.06) in Model 2 (further adjusted for residential area and total energy intake), both statistically significant ( $P < 0.001$ ). Among the metabolic syndrome components, risk was significantly increased for abdominal obesity and impaired fasting glucose levels. For abdominal obesity, the RR was 1.87 (95% CI: 1.32–2.64) in Model 1 and 1.93 (95% CI: 1.36–2.74) in Model 2 (both  $P < 0.001$ ). For impaired fasting glucose, the RR was 1.65 (95% CI: 1.20–2.27) in Model 1 and 1.70 (95% CI: 1.23–2.34) in Model 2 ( $P < 0.01$ ), indicating a clear association with weight gain. No significant associations were ob-

served between weight loss and metabolic indicators.

#### 5. Relative risk for metabolic syndrome and its components by KHEI score and weight change

KHEI scores over the past year were divided into quartiles (Q1–Q4) to estimate RR of metabolic syndrome and its components, comparing the lowest quartile (Q1, low dietary quality) with the highest quartile (Q4, reference) stratified by weight-change status (Table 5). In the weight gain group, participants in the lowest KHEI quartile (Q1) had significantly higher risks for metabolic syndrome and hypertriglyceridemia than those in the highest quartile (Q4). The RR of metabolic syndrome was 2.81 (95% CI: 1.06–7.43) in Model 2 ( $P < 0.05$ ). For hypertriglyceridemia, the RR was 6.76 (95% CI: 1.25–36.61) in Model 1 and 7.29 (95% CI: 1.54–34.61) in Model 2, both indicating significant risk increases ( $P < 0.05$ ). No significant associations were observed between KHEI scores and metabolic indicators in the weight maintenance or weight loss groups.

## DISCUSSION

In the current study, we analyzed the effects of one-year self-reported weight change and dietary quality on the metabolic health of domestic cancer survivors. Our

**Table 4.** Relative risks for metabolic syndrome according to weight change

Variables	Model	Weight maintenance (n = 235)	Weight loss (n = 36)	Weight gain (n = 69)
Metabolic syndrome	1 <sup>1)</sup>	1.00	1.06 (0.64–1.75)	1.98 (1.34–2.93) <sup>***</sup>
	2 <sup>2)</sup>	1.00	1.02 (0.62–1.68)	2.07 (1.40–3.06) <sup>***</sup>
Abdominal obesity	1	1.00	0.71 (0.39–1.30)	1.87 (1.32–2.64) <sup>***</sup>
	2	1.00	0.69 (0.38–1.28)	1.93 (1.36–2.74) <sup>***</sup>
High triglyceride	1	1.00	1.11 (0.53–2.32)	1.13 (0.65–1.98)
	2	1.00	1.03 (0.51–2.09)	1.20 (0.69–2.09)
Low HDL-C	1	1.00	1.33 (0.83–2.15)	1.45 (0.94–2.23)
	2	1.00	1.34 (0.81–2.22)	1.49 (0.97–2.29)
Hyper blood glucose	1	1.00	1.03 (0.71–1.50)	1.65 (1.20–2.27) <sup>**</sup>
	2	1.00	1.02 (0.71–1.47)	1.70 (1.23–2.34) <sup>**</sup>
High blood pressure	1	1.00	0.95 (0.67–1.33)	0.93 (0.60–1.45)
	2	1.00	0.92 (0.66–1.27)	0.97 (0.63–1.51)

Relative risk (95% confidence interval).

HDL-C, high-density lipoprotein cholesterol.

<sup>1)</sup>Model 1: adjusted for age and sex.

<sup>2)</sup>Model 2: adjusted for age, sex, residence area, and total energy intake.

<sup>\*\*</sup> $P < 0.01$ , <sup>\*\*\*</sup> $P < 0.001$ .

**Table 5.** Relative risks for metabolic syndrome according to total KHEI score and weight change

Total KHEI score, Q1 vs. Q4 (reference)	Model	Weight maintenance (n = 235)	Weight loss (n = 36)	Weight gain (n = 69)
Metabolic syndrome	1 <sup>1)</sup>	1.34 (0.76-2.38)	0.54 (0.21-1.37)	2.22 (0.92-5.38)
	2 <sup>2)</sup>	1.39 (0.79-2.45)	0.53 (0.19-1.50)	2.81 (1.06-7.43)*
Abdominal obesity	1	1.31 (0.80-2.15)	0.47 (0.18-1.24)	1.58 (0.80-3.10)
	2	1.37 (0.85-2.20)	0.35 (0.11-1.11)	1.67 (0.82-3.40)
High triglyceride	1	1.78 (0.85-3.74)	0.96 (0.32-2.89)	6.76 (1.25-36.61)*
	2	1.82 (0.88-3.76)	1.20 (0.30-4.70)	7.29 (1.54-34.61)*
Low HDL-C	1	0.97 (0.54-1.77)	1.66 (0.89-3.12)	2.06 (0.86-4.93)
	2	0.82 (0.41-1.62)	1.73 (0.90-3.33)	2.18 (0.88-5.45)
Hyper blood glucose	1	1.02 (0.70-1.48)	0.46 (0.16-1.36)	1.67 (0.86-3.22)
	2	1.03 (0.71-1.50)	0.43 (0.15-1.26)	1.63 (0.77-3.46)
High blood pressure	1	1.20 (0.81-1.77)	0.25 (0.05-1.32)	0.98 (0.31-3.06)
	2	1.23 (0.83-1.82)	0.30 (0.06-1.64)	1.14 (0.67-3.52)

Relative risk (95% confidence interval).

KHEI, Korean Healthy Eating Index; HDL-C, high-density lipoprotein cholesterol.

<sup>1)</sup>Model 1: adjusted for age and sex.

<sup>2)</sup>Model 2: adjusted for age, sex, residence area, and total energy intake.

\*  $P < 0.05$ .

findings revealed that the weight maintenance group had the highest dietary quality, whereas the weight gain group had the lowest. In the weight gain group, lower dietary quality was associated with higher risks of metabolic syndrome and hypertriglyceridemia. Taken together, these results suggest that preventing weight gain and improving dietary quality are crucial for promoting the metabolic health of cancer survivors.

In this study, the weight gain group had a lower average age and a higher proportion of females than the other groups, although the time since cancer diagnosis did not differ significantly: weight maintenance group,  $12.35 \pm 0.48$  years; weight loss group,  $10.86 \pm 1.01$  years; and weight gain group,  $11.84 \pm 0.67$  years. Considering that all subjects were survivors who had lived more than five years since their cancer diagnosis, our findings suggest that weight change cannot be solely explained by the timing of diagnosis or immediate post-treatment effects.

The highest average age of the weight loss group may reflect the effects of sarcopenia and malnutrition, which commonly occur in older survivors. Sarcopenia and metabolic function decline are frequently reported in older cancer survivors and can act as major factors related to weight loss [20]. Therefore, muscle mass preservation and appropriate nutritional management are particularly important in this population.

The prominent weight gain observed in young females aligns with the findings of previous studies. For example, Nyrop *et al.* [21] reported that weight gain was frequent in young female patients with breast cancer during chemotherapy and endocrine therapy, and Fukui *et al.* [22] found similar results. This suggests that awareness of weight management or dietary control behavior after cancer treatment is relatively low in younger populations, and factors such as frequent dining out, irregular meals, and lack of physical activity may affect weight gain [23].

Furthermore, the high proportion of rural residents in the weight loss group indicates the possibility that regional factors influence weight change. In a study conducted among cancer survivors in the United States, rural residents had poorer overall health status and higher health-related unemployment rates than urban residents [24]. Thus, explaining and managing weight change in cancer survivors requires a multifaceted approach that reflects their sociodemographic characteristics, lifestyle habits, and environmental factors.

The high BMI observed in the weight gain group was likely related to increased body fat, which can lead to deterioration of metabolic health [25]. Visceral fat accumulation is closely associated with metabolic syndrome by inducing insulin resistance and inflammatory responses

[26]. In this study, the high risk of metabolic syndrome, abdominal obesity, and impaired fasting glucose in the weight gain group supported this mechanism.

The proportion of patients with elevated blood pressure was the highest in the weight loss group and lowest in the weight gain group, contrary to previous reports [27] showing that weight gain generally increases the risk of hypertension. This may reflect differences in age distribution among the groups. The weight loss group had the highest average age; therefore, age-related arterial stiffness and reduced vascular elasticity may have increased the risk of elevated blood pressure [28]. Sarcopenia and malnutrition, common in older cancer survivors, may also have contributed to blood pressure elevation in combination with vascular function decline [9]. Therefore, the relationship between weight change and blood pressure suggests that multiple factors, including age, changes in body composition, and intentionality of weight loss, should be considered together, rather than solely focusing on weight.

Meanwhile, examining the magnitude of weight change, 68.45% of the weight loss group and 81.39% of the weight gain group experienced changes of 3–6 kg over the past year, with no significant differences between groups in weight control efforts. This suggests that weight change may occur due to involuntary factors, such as metabolic changes, decreased activity levels, and hormonal changes, rather than voluntary lifestyle control. In this regard, Gadéa *et al.* [29] reported that weight changes occurring during chemotherapy are associated with body composition and metabolic abnormalities and can be explained by metabolic mechanisms rather than voluntary efforts. Additionally, Koo *et al.* [30] reported that weight gain is related to metabolic and activity changes post-treatment.

Given that both total energy intake and physical activity level did not differ significantly among weight change groups, differences in weight change and metabolic disease risk may be more closely related to dietary quality or composition rather than simple energy intake or activity level. Therefore, a multifaceted approach combining qualitative improvements in dietary patterns and calorie control is necessary to manage the metabolic health of cancer survivors.

In the current study, the weight maintenance group

showed the highest KHEI score, while the weight gain group had the lowest score, with notable differences in whole grain and total fruit intake. Previous studies have confirmed that the dietary quality in Korean cancer survivors is associated with a lower risk of developing metabolic diseases such as hypertension, diabetes, and dyslipidemia [23]. Specifically, excessive intake of calories, carbohydrates, and fats increased the risk of metabolic syndrome, whereas adequate dietary fiber intake reduced it. Furthermore, in a study based on the National Health and Nutrition Examination Survey in the United States, cancer survivors with high Healthy Eating Index-2015 scores had a lower prevalence of metabolic syndrome [31]. These results support the possibility that the insufficient whole grain and total fruit intakes in the weight gain group may have contributed to the risk of metabolic disease.

In the KHEI quartile analysis within weight change groups, in the weight gain group, participants in the weight gain group with low dietary quality (Q1) had higher risks of metabolic syndrome and hypertriglyceridemia than those with high dietary quality (Q4). This suggests that the combination of weight gain and poor dietary quality may further increase the risk of metabolic health deterioration.

Additionally, studies show that cancer survivors are proactive in health management in the early stages of diagnosis but may neglect dietary quality over time [32]. Continuous nutrition education and systematic management strategies are crucial for effective health management in cancer survivors. Furthermore, because factors such as cancer type, treatment method, diagnosis timing, and lifestyle habits interact complexly to affect metabolic health, dietary quality indicators alone cannot fully explain metabolic disease risk. Accordingly, future research should conduct long-term studies that integrate weight change, dietary quality, and lifestyle habits for more precise analysis.

This study is significant because it comprehensively examined the relationship between metabolic health and cancer survival by simultaneously considering both factors, whereas previous studies have focused on only one of these factors. Effective health management of cancer survivors requires a multidimensional approach that considers the external indicator of weight change,

as well as the qualitative element of dietary quality, with customized management strategies tailored to age, sex, and weight-change patterns.

### Limitations

This study has several limitations. First, the cross-sectional design precluded causal inferences between weight change and metabolic outcomes. Second, both weight change and dietary intake data were self-reported, which may have introduced a recall bias or measurement error. Third, weight change was based on a one-year recall, whereas dietary quality was assessed using a single-day 24-hour recall, potentially limiting the reflection of long-term habits. Fourth, in the subgroup analyses of KHEI quartiles and metabolic outcomes, some CIs were wide, likely due to the limited sample size and heterogeneity.

Despite these limitations, this study provides valuable insights by comprehensively evaluating the interplay between weight change and dietary quality in long-term cancer survivors. These findings provide a foundation for future interventions aimed at metabolic disease prevention and health promotion in this population. Longitudinal, cancer-type-specific studies incorporating objective dietary and anthropometric measures are warranted.

### Conclusion

This study investigated metabolic syndrome and its associated risk factors in Korean adult cancer survivors according to recent weight-change patterns and dietary quality. Collectively, our findings suggest that improving lifestyle habits, particularly enhancing dietary quality, is as important as weight management in post-cancer healthcare. Cancer survivors who experience weight gain or loss require nutritional and metabolic management strategies tailored to their condition, which may help prevent metabolic diseases and promote long-term health.

### CONFLICT OF INTEREST

The corresponding author, Ji-Myung Kim, serves as Editor-in-Chief of the *Korean Journal of Community Nutrition*. To mitigate potential conflicts of interest, Ji-Myung

Kim abstained from the peer review and editorial decision-making processes for this manuscript, which was handled by an independent editor. The authors declare no conflicts of interest.

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### DATA AVAILABILITY

Data supporting the findings of this study are openly available from the KNHANES at <https://knhanes.kdca.go.kr/knhanes/main.do>.

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