



■ Original Article

Gender Difference of the Association between Energy Intake Expenditure Balance and Depression among Korean Adults: A Cross-Sectional Study from the 2014, 2016, and 2018 Korea National Health and Nutrition Examination Survey

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Background: Diet and physical activity are key factors related to depressive mood. Previous studies have demonstrated the effects of diet and physical activity on depression. However, the effect of energy intake-expenditure balance (EIEB) on mental health has not been fully evaluated. This study aimed to analyze the association between EIEB and depression.

Methods: A total of 13,460 participants (5,660 men and 7,800 women) aged ≥ 19 years were obtained from the 2014, 2016, and 2018 Korea National Health and Nutrition Examination Survey (KNHANES). EIEB was defined as the difference between the daily energy intake and energy expenditure. Energy intake was calculated and provided by the KNHANES using a 24-hour recall survey. Energy expenditure was estimated as the sum of basal metabolic rate and physical activity. Logistic regression analyses were used to investigate the association between sex-specific quartile groups (Q1-Q4) of EIEB and depression after adjusting for socioeconomic status, body mass index, lifestyle factors, and underlying diseases.

Results: Women in Q3 of EIEB (211-669 kcal) had a significantly lower risk of depression (odds ratio [OR], 0.78; 95% confidence interval [CI], 0.67-0.92) than those in Q1 of EIEB (< -167 kcal). The adjusted ORs of depression were 0.87 (95% CI, 0.75-1.02) in Q2 and 0.86 (95% CI, 0.74-1.01) in Q4, with P for trend=0.030. There were no significant associations between the EIEB quartile groups and depression in men after adjusting for potential confounders (P for trend=0.564).

Conclusion: Our results suggested that the EIEB is negatively associated with depression in Korean women.

Keywords: Energy Intake; Energy Expenditure; Depression; Gender Difference

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INTRODUCTION

Depression is believed to disturb daily life activities and lower the quality of life.¹⁾ Although depression is not categorized as a non-communicable disease, the burden of psychological disorders in middle- or high-income countries cannot be ignored.²⁾

Poor diet and lack of physical activity are thought to be contributory to depressive moods.³⁾ Studies have found relationships between diet, depression, physical activity, and depression. In a recent randomized trial, long-term intake of a Mediterranean diet was beneficial for patients with depression and type 2 diabetes mellitus.⁴⁾ In addition, some cohort studies have reported that a healthy diet reduces the likelihood of depression.⁵⁾ Higher physical activity significantly decreased the risk of depressive mood in Korean adults with chronic diseases.⁶⁾

However, energy intake and expenditure are interrelated and cannot be altered in a dependent manner without compensatory changes. The components of the energy balance influence each other through several physiological controls involving hormonal signals and neural systems to maintain body mass.^{7,8)} Although the impact of diet and physical activity on depression are well established, little is known about the effect of energy intake-expenditure balance (EIEB) on mental health. Therefore, this study examined the association between EIEB and depression in Korean adults.

METHODS

1. Study Participants

We used data from the 2014, 2016, and 2018 Korea National Health and Nutritional Examination Survey (KNHANES). The KNHANES is based on the Korean population from a cross-sectional survey conducted by the Korea Disease Control and Prevention Agency using a complex, multistage, probability-sampling model.⁹⁾ In this study, data from all 3 years were included because the Patient Health Questionnaire-9 (PHQ-9) and Global Physical Activity Questionnaire (GPAQ) were surveyed in these 3 years.

The Institutional Review Board (IRB) of Seoul National University Hospital approved this study (IRB approval no., 2208-108-1351) and written informed consent was waived for a secondary use of previously collected data. From a total of 23,692 participants, we excluded those with an incomplete PHQ-9 questionnaire (n=7,064), a diagnosis of de-

pression (n=800), a daily energy intake of more than 5,000 kcal or less than 500 kcal (n=2,224), and no data about socioeconomic status (education, marital state, income, living state), body mass index (BMI) measurement (height, weight), or lifestyle factors (smoking, drinking). Consequently, the final study population comprised 13,460 participants aged ≥ 19 years (Figure 1).

2. Energy Intake Evaluation

Energy intake was obtained from the KNHANES dataset, which used a 24-hour recall method to calculate energy intake.

3. Energy Expenditure Evaluation

The KNHANES used the GPAQ to assess weekly frequency and daily hours of vigorous and moderate intensity physical activity to assess the participants' daily energy expenditure. The GPAQ defines vigorous intensity physical activity as activities causing a high increase in breathing or heart rate for more than 10 minutes and moderate intensity as activities causing a small increase in breathing or heart rate for more than 10 minutes. It also uses a questionnaire about weekly frequency and daily hours of walking. We calculated physical activity calories using the metabolic equivalent of task (MET), transferring vigorous-intensity physical activity as 8.0 METs, moderate-intensity physical activity as 4.0 METs, and walking as 3.3 METs. Then, we used the formula: $1 \text{ kcal} = 3.5 \times \text{MET} \times \text{weight} / 200$.^{10,11)}

We then calculated daily energy expenditure by adding physical activity to the calculated basal metabolic rate (BMR) using the Harris-Benedict equation. Finally, we calculated EIEB by subtracting energy expenditure from energy intake. The participants were categorized into four groups according to the EIEB (kcal) in both the male and female groups, separately: 1st quartile (Q1: $E < -122$), 2nd quartile (Q2: $-122 \leq E < 396$), 3rd quartile (Q3: $396 \leq E < 989$), and 4th quartile (Q4: $989 \leq E$) in male and 1st quartile (Q1: $E < -167$), 2nd quartile (Q2: $-167 \leq E < 211$), 3rd quartile (Q3: $211 \leq E < 669$), and 4th quartile (Q4: $669 \leq E$) in female.

4. Assessment of Depression

The KNHANES evaluates the participants' degree of depression using the Korean version of the PHQ-9. The Korean version of the PHQ-9 consists of nine questions on loss of interest, depressive mood, sleep behavioral change, easy fatigability, appetite change, guilt or useless

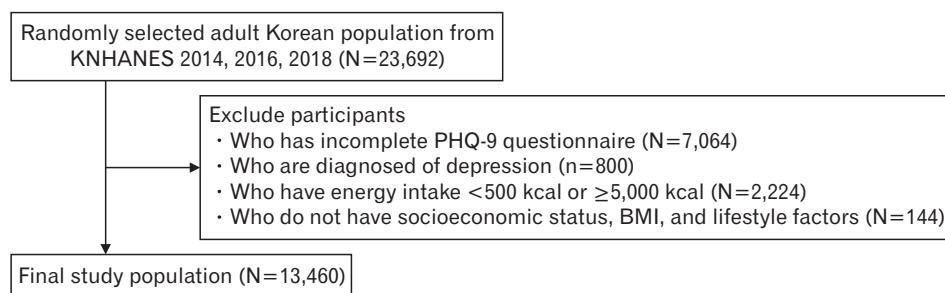


Figure 1. Study population flow chart. KNHANES, Korea National Health and Nutrition Examination Survey. PHQ-9, Patient Health Questionnaire-9; BMI, body mass index.

feelings, trouble in concentration, retardation or agitation, and ideation of suicide or self-harm. The Korean version of the PHQ-9 has significant sensitivity and specificity for diagnosing major depressive disorder and depressive episodes in bipolar disease.¹² We set the criterion for depression as a score of 5 using the Korean version of the PHQ-9.¹³

5. Confounding Variables

The confounding variables included socioeconomic status, BMI, lifestyle factors, and underlying diseases. Socioeconomic status included age, education level, marital status, income level, and living status. Educational level was categorized into three groups: lower than high school, high school graduate, and higher than high school. Marital status was categorized into two groups: married and unmarried. The income level was categorized into three groups: low (0%–25%), middle (25%–75%), and high (75%–100%). Living status was categorized into two groups: living alone and living with others.

Lifestyle factors including smoking and alcohol consumption were also assessed. Smoking status was categorized into three groups: never smokers, former smokers, and current smokers. Alcohol consumption was categorized into two groups: non-high-risk and high-risk. High-risk drinking was defined based on the World Health Organization (WHO) definition as consuming more than 60 g of pure alcohol per day for men and more than 40 g of pure alcohol for women.¹⁴ According to this definition, high-risk drinking in Korean adults is defined as consuming more than seven cups of soju for men and five cups of soju for women, with frequency as drinking more than twice a week.

Underlying diseases included whether the participants were diagnosed with cardiovascular disease, cerebrovascular disease, or cancer and whether they were on medication for diabetes mellitus (DM), dyslipidemia (DL), and hypertension (HTN).

The diet quality was quantified using the mean adequacy ratio (MAR), which is the average nutrient adequacy ratio (NARs) of protein, vitamin A, thiamine, riboflavin, niacin, vitamin C, calcium, phosphorus, and iron. The NAR was calculated using the following equation: daily intake of the nutrient/recommended intake of the nutrient according to the 2020 Dietary Reference Intakes for Koreans.^{15,16}

6. Statistical Analysis

The characteristics of the study participants according to sex and PHQ-9 score are presented as the mean±standard error or the number (percentage). A t-test was conducted to compare the means of continuous variables and a chi-square test was performed to compare categorical variables.

Odds ratios (OR) for depression according to sex-specific quartile groups of EIEB were tested using logistic regression analysis, with the sex-specific 1st quartile group used as the reference group. Four models were designed after adjusting for confounding variables. Model 1 was tested using logistic regression analysis without any adjustment. Model 2 was tested using a multiple logistic regression analysis adjusted for age. Model 3 was tested after adjusting for BMI, educational level, marital status, income level, living status, smoking status, and alco-

hol consumption. Model 4 was tested with adjustments for cardiovascular disease, cerebrovascular disease, cancer diagnosis, and DM, DL, and HTN medication history, in addition to all the variables adjusted in model 3. Trend analyses are conducted on the models.

We also examined the association between energy intake and depressive moods. The participants were categorized into quartiles according to energy intake, and four models were used for statistical analysis similar to the analysis with EIEB, with the difference that physical activity was also considered a confounding factor in model 4. Multivariate logistic regression was used for analysis.

A subgroup analysis was performed to stratify the participants according to age, BMI, diet quality, physical activity, and occupational activity. The participants were divided into two groups according to each variable. For age, diet quality, and physical activity, the median values were used to classify the patients into two groups, and a BMI of 25 kg/m² was used to divide the patients into obese and non-obese groups in accordance to the WHO and Asia-Pacific guidelines.¹⁷ We categorized the participants' occupations into sedentary and active groups. Sedentary occupations included homemakers, office workers, and simple laborers.¹⁸ Quartiles of EIEB were used, and the ORs were calculated by adjusting for age, BMI, educational level, marital status, income level, living status, smoking and alcohol consumption, cardiovascular disease, cerebrovascular disease, cancer diagnosis, and DM, DL, and HTN medication history. Multivariate logistic regression was used for the subgroup analysis.

In all statistical analyses, two-sided P-values under 0.05 were considered statistically significant. Statistical analyses were performed using STATA ver. 16.0 software (Stata Corp., College Station, TX, USA).

RESULTS

1. Basal Characteristics of Study Participants

In our study, 13,460 participants aged ≥19 years (5,660 [42.0%] males and 7,800 [58.0%] females) were included. The prevalence of depression was 13.4% (n=761) in males and 21.5% (n=1,675) in females. The mean age was one year younger in the depression group than in the non-depression group for both sexes (Table 1). There was a significantly higher prevalence of depression in the participants with low education, unmarried status, low income, and living alone among both males and females compared to their counterparts. Current smokers and high-risk alcoholic drinkers had a higher prevalence of depression compared to the others.

The mean energy intake was approximately 40 kcal/d lower in the depressive group than in the non-depressive group for both males and females; the difference was not statistically significant in males. Carbohydrate intake and diet quality were significantly lower in the depressive group than in the non-depressive group in both the male and female participants. There was a significant difference in protein intake among the females. BMR, physical activity, and daily energy intake showed no significant differences between the depression and non-depression groups in either males or females. The EIEB was signifi-

Table 1. Basal characteristics of the study participants according to depression and sex

Characteristic	Male (N=5,660)			Female (N=7,800)		
	PHQ-9 <5	PHQ-9 ≥5	P-value	PHQ-9 <5	PHQ-9 ≥5	P-value
No. of participants	4,899	761		6,125	1,675	
Age (y)	51.9±16.8	50.6±17.9	0.060	51.0±16.0	49.8±18.2	0.014
Body mass index (kg/m ²)	24.5±3.3	24.1±3.6	0.013	23.5±3.5	23.3±3.7	0.051
Education			0.004			0.001
Less than high school	1,265 (25.8)	231 (30.4)		2,049 (33.5)	639 (38.2)	
High school graduate	1,657 (33.8)	267 (35.1)		1,936 (31.6)	501 (29.9)	
Beyond high school	1,977 (40.4)	263 (34.6)		2,140 (34.9)	535 (31.9)	
Marital status			<0.001			<0.001
Married	4,012 (81.9)	569 (74.8)		5,411 (88.3)	1,366 (81.6)	
Unmarried	887 (18.1)	192 (25.2)		714 (11.7)	309 (18.5)	
Income percentage			<0.001			<0.001
Low (0%–25%)	781 (16.0)	189 (24.8)		1,052 (17.2)	438 (26.2)	
Middle (25%–75%)	2,617 (53.4)	389 (51.1)		3,213 (52.5)	869 (51.9)	
High (75%–100%)	1,501 (30.7)	183 (24.1)		1,860 (30.4)	368 (22.0)	
Living alone			<0.001			<0.001
Yes	435 (8.9)	121 (15.9)		675 (11.0)	271 (16.2)	
No	4,464 (91.1)	640 (84.1)		5,450 (89.0)	1,404 (83.8)	
Smoking status			<0.001			<0.001
Never	1,184 (24.2)	155 (20.4)		5,634 (92.0)	1,381 (82.5)	
Former	2,141 (43.7)	262 (34.4)		285 (4.7)	146 (8.7)	
Current	1,574 (32.1)	344 (45.2)		206 (3.4)	148 (8.8)	
Alcohol drinking			0.001			<0.001
High-risk drinking	837 (17.1)	167 (21.9)		264 (4.3)	125 (7.5)	
Non-high risk drinking	4,066 (82.9)	594 (78.1)		5,861 (95.7)	1,550 (92.5)	
Diet						
Energy intake (kcal/d)	2,290.5±845.9	2,252.5±835.3	0.248	1,715.7±653.0	1,674.1±707.8	0.030
Protein intake (g/d)	81.3±39.0	78.7±42.3	0.115	60.5±29.3	58.2±31.4	0.007
Fat intake (g/d)	48.5±34.7	47.3±34.2	0.372	37.3±26.9	36.5±28.7	0.352
Carbohydrate intake (g/d)	340.6±122.9	328.8±123.1	0.014	276.1±108.0	265.8±113.4	<0.001
Diet quality	1.196±0.521	1.148±0.526	0.018	1.063±0.500	1.010±0.506	<0.001
Basal metabolic rate (kcal/d)	1,558.4±231.1	1,557.7±243.6	0.944	1,250.0±123.9	1,251.2±143.1	0.757
Physical activity (kcal/d)	283.6±418.0	304.8±568.7	0.322	173.4±254.4	178.4±324.6	0.560
Daily energy expenditure (kcal/d)	1,841.9±512.6	1,862.6±662.6	0.412	1,423.4±297.7	1,429.6±381.1	0.539
Energy intake-expenditure balance (kcal/d)	448.6±919.3	389.9±957.6	0.114	292.3±697.9	244.5±753.1	0.020
Pre-medical history						
Diagnosed of cardiovascular or cerebrovascular disease	302 (6.2)	56 (7.36)	0.239	182 (3.0)	96 (5.7)	<0.001
Diagnosed of cancer	205 (4.2)	48 (6.3)	0.011	324 (5.3)	98 (5.8)	0.402
On hypertension medication	1,148 (23.4)	181 (23.8)	0.87	1,284 (21.0)	349 (20.8)	0.936
On diabetes mellitus medication	456 (9.3)	102 (13.4)	<0.001	428 (7.0)	155 (9.2)	0.002
On dyslipidemia medication	484 (9.9)	83 (10.9)	0.416	747 (12.2)	213 (12.7)	0.594

Values are presented as mean±standard error or number (%). P-values were calculated using t-test for continuous variables and chi-square test for categorical variables. Patient Health Questionnaire-9.

cantly lower in the women of the depressive group.

Women diagnosed with cardiovascular or cerebrovascular disease had a higher prevalence of depression, and men diagnosed with cancer had a higher prevalence of depression. The participants taking DM medications had a higher prevalence of depression in the males and the females; however, there were no differences with the DL or HTN medications.

2. Association between Energy Intake-Expenditure Balance and Depression

The associations between EIEB and depression in the male and female

participants are shown in (Table 2). The ORs of depression in the male participants did not increase or decrease significantly according to the EIEB in any model. In model 4, the adjusted ORs of depression in Q2 (-122≤ EIEB <396), Q3 (396≤ EIEB <989), and Q4 (989≤ EIEB) were 1.20 (95% confidence interval [CI], 0.96–1.49), 1.01 (95% CI, 0.80–1.26), and 0.99 (95% CI, 0.79–1.24), respectively, with the 1st quartile as a reference group.

In contrast, the ORs of depression in the female participants was decreased in the groups with higher EIEB than in the reference group and was decreased in the 3rd quartile group in all four models. After adjustment, the decrease in OR in the 3rd quartile group remained

Table 2. Odds ratios and 95% confidence intervals of depressive mood according to energy intake-expenditure balance

Variable	Energy intake-expenditure balance (kcal/d)				P for trend
	1st quartile (0%–25%)	2nd quartile (25%–50%)	3rd quartile (50%–75%)	4th quartile (75%–100%)	
Male					
No. of participants	1,415	1,415	1,415	1,415	
No. of PHQ-9 ≥5	184	210	181	186	
Model 1	1 (Ref)	1.17 (0.94–1.44)	0.98 (0.79–1.22)	1.01 (0.81–1.26)	0.701
Model 2	1 (Ref)	1.19 (0.96–1.48)	1.00 (0.80–1.25)	1.01 (0.81–1.26)	0.711
Model 3	1 (Ref)	1.18 (0.95–1.47)	0.99 (0.79–1.25)	0.96 (0.77–1.21)	0.430
Model 4	1 (Ref)	1.20 (0.96–1.49)	1.01 (0.80–1.26)	0.99 (0.79–1.24)	0.564
Female					
No. of participants	1,950	1,950	1,950	1,950	
No. of PHQ-9 ≥5	473	414	380	408	
Model 1	1 (Ref)	0.84 (0.72–0.98)*	0.76 (0.65–0.88)*	0.83 (0.71–0.96)*	0.005
Model 2	1 (Ref)	0.85 (0.73–0.99)*	0.76 (0.66–0.89)*	0.82 (0.71–0.96)*	0.004
Model 3	1 (Ref)	0.86 (0.74–1.00)	0.78 (0.67–0.91)*	0.85 (0.73–1.00)	0.025
Model 4	1 (Ref)	0.87 (0.75–1.02)	0.79 (0.67–0.92)*	0.86 (0.74–1.01)	0.030

Statistical differences were tested using logistic regression analysis using following four models: model 1: not adjusted; model 2: adjusted for age; model 3: adjusted with body mass index, educational level, marital status, income level, living status, smoking, and alcohol consumption in addition to model 2; model 4: adjusted with cardiovascular and cerebrovascular disease, cancer diagnosis and diabetes mellitus, dyslipidemia, and hypertension medication in addition to model 3.

PHQ-9, Patient Health Questionnaire-9; Ref, reference.

* $P < 0.05$.

significant. In model 4, the adjusted OR of depression in Q2 (167 ≤ EIEB < 211), Q3 (211 ≤ EIEB < 669), and Q4 (989 ≤ EIEB) were 0.87 (95% CI, 0.75–1.02), 0.79 (95% CI, 0.67–0.92), and 0.86 (0.74–1.01), respectively, with 1st quartile as a reference group. Additionally, there was a statistically significant decreasing trend in depressive mood according to the increase in EIEB quartiles in all four models.

The female participants in 3rd quartile had significantly lower odds of depression than those in the first quartile, with an OR of 0.79. However, there were no significant associations between the EIEB quartile groups and depression in the male participants.

We also examined the association between energy intake and depressive moods in the women and men. Similar to the EIEB results, energy intake was not significantly associated with depressive mood in men. However, higher energy intake was significantly associated with depressive mood in all 2nd, 3rd, and 4th quartile groups with an OR of 0.81 (95% CI, 0.69–0.94), 0.71 (95% CI, 0.61–0.83), and 0.85 (95% CI, 0.73–0.99), respectively. Trend analysis revealed a decreasing trend in the risk of depressive mood as energy intake increased ($P = 0.016$) (Supplement 1).

3. Subgroup Analysis

After analyzing the association between EIEB and depression, we conducted several subgroup analyses according to age, BMI, diet quality, and occupational activity. All participants were divided into two subgroups: according to age (<53 years versus ≥53 in men, <51 years versus ≥51 in women), BMI (<25 kg/m² versus ≥25 kg/m²), diet quality (<1.10 versus ≥1.10 in men, <0.97 versus ≥0.97 in women), physical activity (<164.5 kcal/d versus ≥164.5 kcal/d in men, <93.4 kcal/d versus ≥93.4 kcal/d in women), and occupational activeness (sedentary versus active), respectively. Subgroup analyses of the male and female

participants are shown in Table 3.

For the male participants, there was no significant relationship between the EIEB quartile groups and depression. Only the 2nd quartile EIEB was associated with a marginally increased risk of depressive mood in obese patients with an OR of 1.38 (95% CI, 0.99–1.92).

For the female participants, the association between the quartile groups of EIEB and depression was significant in patients aged ≥51 years. The 3rd and 4th quartile groups in the EIEB had a significantly lower OR compared to the 1st quartile with an OR of 0.77 (95% CI, 0.62–0.96) and 0.75 (95% CI, 0.60–0.95). There was also a statistically significant trend for depressive mood in the older age group with a P -value of 0.014. Similar to the results in Table 2, the 3rd quartile EIEB had a significantly lower risk of depression than the 1st quartile in the non-obese/obese group, low diet quality group, high physical activity group, and sedentary/active occupation group. The ORs of depression in the obese group was generally lower than those in the non-obese group, with an OR of 0.78 (95% CI, 0.59–1.02) in the 2nd quartile, 0.73 (95% CI, 0.55–0.98) in the 3rd quartile, and 0.76 (95% CI, 0.57–1.02) in the 4th quartile. In the low diet quality group, the 3rd quartile group had a significantly lower OR compared to the 1st quartile with an OR of 0.76 (95% CI, 0.61–0.94). However, there was no significant difference in the risk for depression in the higher-quality group. Physically active participants had a lower OR than the physically inactive participants. The ORs in the 2nd and 3rd quartile groups in the physically active patients were 0.74 (95% CI, 0.59–0.92) and 0.69 (95% CI, 0.55–0.87), respectively. Lastly, both sedentary and active occupational groups showed a significant relationship between EIEB and depression in the 3rd quartile group, with an OR of 0.82 (95% CI, 0.69–0.97) and 0.58 (95% CI, 0.37–0.90).

Table 3. Subgroup analysis: stratification according to age, BMI, diet quality, and occupational activeness

Variable	No. of participants	Energy intake-expenditure balance (kcal/d)								P for trend
		1st quartile (0%–25%)		2nd quartile (25%–50%)		3rd quartile (50%–75%)		4th quartile (75%–100%)		
		PHQ-9 ≥5	OR (95% CI)	PHQ-9 ≥5	OR (95% CI)	PHQ-9 ≥5	OR (95% CI)	PHQ-9 ≥5	OR (95% CI)	
Male										
Age <53 y	2,809	104	1 (Ref)	98	1.23 (0.91–1.67)	94	1.18 (0.87–1.62)	104	0.94 (0.69–1.28)	0.657
Age ≥53 y	2,851	80	1 (Ref)	112	1.17 (0.85–1.61)	87	0.86 (0.62–1.21)	82	1.08 (0.77–1.54)	0.914
BMI <25 kg/m ²	3,407	93	1 (Ref)	126	1.10 (0.81–1.48)	131	1.02 (0.76–1.38)	129	0.94 (0.70–1.27)	0.619
BMI ≥25 kg/m ²	2,253	91	1 (Ref)	84	1.38 (0.99–1.92)	50	0.94 (0.64–1.37)	57	1.08 (0.74–1.56)	0.796
Diet quality <1.10	2,830	151	1 (Ref)	148	1.20 (0.92–1.55)	68	0.81 (0.58–1.11)	33	1.16 (0.73–1.80)	0.940
Diet quality ≥1.10	2,830	33	1 (Ref)	62	1.19 (0.75–1.89)	113	1.18 (0.78–1.83)	153	0.98 (0.66–1.51)	0.939
PA <164.5 kcal/d	2,985	127	1.15 (0.83–1.59)	112	0.90 (0.65–1.26)	123	0.96 (0.69–1.35)	127	1.15 (0.83–1.59)	0.500
PA ≥164.5 kcal/d	2,675	83	1.17 (0.85–1.60)	69	1.07 (0.76–1.48)	63	0.92 (0.65–1.30)	83	1.17 (0.85–1.60)	0.548
Sedentary occupation	3,743	129	1 (Ref)	154	1.36 (1.05–1.77)	117	1.07 (0.81–1.42)	133	1.22 (0.93–1.61)	0.417
Active occupation	1,917	55	1 (Ref)	56	0.93 (0.62–1.41)	64	0.91 (0.61–1.36)	53	0.69 (0.46–1.06)	0.097
Female										
Age <51 y	3,874	247	1 (Ref)	195	0.94 (0.75–1.17)	175	0.82 (0.65–1.03)	238	0.99 (0.80–1.22)	0.616
Age ≥51 y	3,926	226	1 (Ref)	219	0.82 (0.66–1.02)	205	0.77 (0.62–0.96)*	170	0.75 (0.60–0.95)*	0.014
BMI <25 kg/m ²	5,520	289	1 (Ref)	297	0.92 (0.76–1.12)	287	0.81 (0.67–0.98)*	316	0.91 (0.76–1.10)	0.180
BMI ≥25 kg/m ²	2,280	184	1 (Ref)	117	0.78 (0.59–1.02)	93	0.73 (0.55–0.98)*	92	0.76 (0.57–1.02)	0.064
Diet quality <0.97	3,900	408	1 (Ref)	311	0.96 (0.80–1.14)	159	0.76 (0.61–0.94)*	45	0.83 (0.57–1.19)	0.169
Diet quality ≥0.97	3,900	65	1 (Ref)	103	0.71 (0.50–1.01)	221	0.84 (0.61–1.17)	363	0.92 (0.68–1.25)	0.862
PA <93.4 kcal/d	3,900	166	1 (Ref)	251	0.97 (0.77–1.23)	237	0.84 (0.66–1.06)	240	0.81 (0.64–1.02)	0.033
PA ≥93.4 kcal/d	3,900	307	1 (Ref)	163	0.74 (0.59–0.92)*	143	0.69 (0.55–0.87)*	168	0.91 (0.73–1.14)	0.358
Sedentary occupation	6,611	413	1 (Ref)	364	0.89 (0.76–1.05)	331	0.82 (0.69–0.97)*	345	0.88 (0.74–1.04)	0.090
Active occupation	1,189	60	1 (Ref)	50	0.69 (0.44–1.08)	49	0.58 (0.37–0.90)*	63	0.75 (0.50–1.14)	0.131

Statistical differences were tested using logistic regression analysis with adjustment of age, BMI, educational level, marital status, income level, living status, smoking, alcohol consumption, cardiovascular and cerebrovascular disease, cancer diagnosis and diabetes mellitus, dyslipidemia, and hypertension medication history.

PHQ-9, Patient Health Questionnaire-9; OR, odds ratio; CI, confidence interval; Ref, reference; BMI, body mass index; PA, physical activity.

*P<0.05.

DISCUSSION

In this study, the female participants showed a negative relationship between the EIEB quartile groups and depression, whereas the male participants showed no significant relationship. As EIEB is the result of subtracting energy expenditure from energy intake, a higher EIEB indicates excess energy intake compared with energy expenditure. In our study, the lowest likelihood of depression group was in the 3rd quartile group of the EIEB, with an OR of 0.79 for depression in women. In other words, the women with the score $211.3 \leq \text{EIEB} < 668.5$ had the lowest risk of depression. On the other side, women participants with EIEB lower than -167.2 had the highest risk of depression. The results suggested that balanced energy intake and expenditure are important for mental health in females, and poor energy intake compared to energy expenditure adversely affects females' mental health. In addition, the highest EIEB group had a slightly higher odds of depression than the third quartile group. This result implied that surplus energy reduces the risk of depression; however, the benefits of surplus energy can be reduced if it becomes too excessive.

Subgroup analysis showed consistent results with a significant association between EIEB and depressive mood in females and no association in males. We stratified the participants according to age, obesity, diet quality, physical activity, and occupational physical activity to determine the differences in the associations in specific patient groups. Among the female participants, older females, obese individuals, participants with lower diet quality, and physically active groups were more susceptible to the association between EIEB and depressive mood.

A negative relationship between the quartile groups of EIEB and depression was shown only in the female participants. This indicated that women are more mentally sensitive to EIEB than men. According to the Korean Ministry of Health and Welfare, men aged 50–64 years tend to have excess energy intake than energy requirement, and women aged 19–29 years and ≥ 70 years have less energy intake than energy requirement. In contrast, the Korean population tends to have a similar energy intake that is according to sex and age compared to energy requirement.¹⁹⁾ This could lead to sex differences in mental sensitivity to EIEB. Our study results partially coincided with those of a previous study by Begdache et al.,²⁰⁾ which showed that women are more mentally vulnerable to dietary intake than men. They suggested that dietary deficiency in men and dietary sufficiency in women had a more profound effect on mental health via the regulation of the limbic system.²⁰⁾

Based on our results, we used energy intake instead of EIEB, and a higher energy intake was significantly associated with a lower risk of depressive mood. This result correlated with the finding that energy intake was lower in the depressive group, and physical activity did not differ between the depressive and non-depressive groups (Table 1). Since EIEB is calculated as the difference between energy intake and energy expenditure, we can infer that energy intake plays an essential role that is associated with depressive mood. In the subgroup analysis

according to physical activity, the physically active and active occupation groups showed lower odds for depression in the 3rd quartile group of EIEB, which means adequate EIEB might be especially important in females with high energy expenditure. Although daily energy intake could be a key component in explaining energy balance and depression, EIEB at the individual level might explain this relationship better than energy intake by simply adjusting for the mean physical activity level of the study population. However, further studies are required to clarify this point.

In this study, the causal relationship between EIEB and depression was unclear owing to its cross-sectional design; however, leptin could be a possible explanation. Leptin is secreted by the adipose tissue and plays a primary role in controlling the homeostasis of energy intake and expenditure. When a human's physiological status is in an energy deficit state, leptin levels decrease, whereas they increase with excess energy.²¹⁾ Moreover, studies have demonstrated that insufficient leptin levels affect depression and anxiety through structural and functional changes in neural plasticity in the hippocampus and prefrontal cortex, mediated by white adipose tissue.^{22,23)} Positive EIEB could be associated with sufficient leptin production and is less likely to lead to a depressive mood.

Our study had several strengths. The data for our study are from the KNHANES, which relies on a nationally representative survey and a large number of participants. Our study analyzed the effects of energy intake and expenditure balance on the risk of depression, which could reflect lifestyle factors related to mental health more comprehensively. To the best of our knowledge, this is the first cross-sectional study that investigated the association between EIEB and depression in the general population.

This study had some limitations. First, the cross-sectional design limited our ability to determine a causal relationship between EIEB and the likelihood of depression. Second, we calculated the estimated daily energy expenditure by adding physical activity and BMR. Daily energy expenditure consists of activity-related energy expenditure (physical activity), resting energy expenditure (BMR), and cold- or diet-induced thermogenesis.²⁴⁾ However, the assessment of thermogenesis was not possible with our data; we replaced real EIEB with an incomplete form of estimated EIEB defined by adding physical activity and BMR. Third, we classified the participants as sedentary or active according to their occupation. However, even within the same occupational group, physical activity can vary according to occupation. Fourth, since the PHQ-9 is a useful screening tool for depression, the results could be different in clinically diagnosed patients with depression. Finally, dietary variables were estimated by a single 24-hour dietary recall, which might not reproduce the actual data at an individual level without considering the daily variation in diet.

In conclusion, positive energy intake and expenditure balance are negatively associated with depression in Korean women, but not in men. This study showed that monitoring individual daily energy balances is necessary, especially in women. Further prospective studies are needed to identify the causal relationship and underlying mecha-

nisms between EIEB and depression for the management of mental health.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIALS

Supplementary materials can be found via <https://doi.org/10.4082/kjfm.22.0165>. Supplement 1. Odds ratios and 95% confidence intervals of depressive mood according to energy intake.

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