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Effect of Breakfast Consumption and Meal Time Regularity on Nutrient Intake and Cardiometabolic Health in Korean Adults

So Ra Yoon [1], **Miok Choi** [2,3] **Oh Yoen Kim** [2,4]

[1]Institute of Health Insurance and Clinical Research, National Health Insurance Service Ilsan Hospital, Goyang, Korea
[2]Department of Food Science and Nutrition, Dong-A University, Busan, Korea
[3]Dietetic Department, Dong-A University Hospital, Busan, Korea
[4]Department of Health Sciences, Dong-A University, Busan, Korea

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Correspondence to
Miok Choi
Dietetic Department, Dong-A University Hospital, 26 Daesingongwon-ro, Seo-gu, Busan 49201, Korea.
E-mail: cmo117@hanmail.net

Oh Yoen Kim
Department of Food Science and Nutrition, Dong-A University, 37 Nakdong-daero 550beon-gil, Saha-gu, Busan 49315, Korea.
E-mail: oykim@dau.ac.kr

ORCID iDs
So Ra Yoon
https://orcid.org/0000-0003-2277-0594
Miok Choi
https://orcid.org/0000-0002-4016-3168
Oh Yoen Kim
https://orcid.org/0000-0001-9262-3309

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ABSTRACT

Objective: Dietary factors are important contributors to obesity and related metabolic disorders. Few studies have evaluated the impact of dietary habits (*e.g.*, breakfast consumption frequency and meal regularity) on metabolic health. We investigated the effects of breakfast consumption frequency and meal time regularity on nutrient intake and cardiometabolic status in Korean adults.
Methods: Participants without diagnosed diseases (n=217) were examined for anthropometric and biochemical parameters, lifestyle, dietary habits, and nutrient intake. They were categorized into 4 groups by breakfast consumption frequency (≥6 or <6 times/week) and meal time regularity (regular or irregular): breakfast ≥6 times/week and regular eating (HBRE), breakfast ≥6 times/week and irregular eating (HBIE), breakfast <6 times/week and regular eating (LBRE) and breakfast <6 times/week and irregular eating (LBIE).
Results: Participants in the LBIE group were the youngest, had higher waist circumference, body mass index, triglyceride levels, and inflammation, and consumed the highest daily total caloric intake (TCI), the highest proportion of fats, and the lowest proportion of carbohydrates. The LBIE group also had the lowest proportion of energy intake at breakfast and the highest proportion at dinner. The LBIE group consumed the lowest amounts of fiber, beta-carotene, vitamin K, folate, calcium and iron, and had the highest prevalence of inadequate nutrient intake for TCI, protein, vitamins A, C, B6, and B12, folate, calcium, iron, zinc, and copper.
Conclusion: Regular breakfast consumption and meal times are related to healthy lifestyle habits and adequate nutrient intake, which affect metabolic health, thereby helping prevent obesity and related metabolic disorders.

Keywords: Breakfast; Meals; Nutrients; Health

INTRODUCTION

Cardiovascular disease (CVD) is a global public health concern, as it is the leading cause of death worldwide.[1] In South Korea (hereafter, Korea), cardiac disease is the single highest cause

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Conflict of Interest
The authors have no conflicts of interest to declare.

Author Contributions
Conceptualization: Choi M, Kim OY; Data curation: Yoon SR; Formal analysis: Yoon SR, Kim OY; Funding acquisition: Kim OY; Project administration: Kim OY; Supervision: Kim OY; Writing - original draft: Yoon SR, Kim OY; Writing - review & editing: Choi M, Kim OY.

of mortality (60.4 per 100,000 persons in 2019, Statistics in Korea).[2] The optimal management of patients with CVD or people at a high risk of CVD requires the assessment and treatment of several modifiable cardiometabolic risk factors following evidence-based guidelines.[3]

Several conditions associated with the development of CVD, such as obesity, diabetes mellitus (DM), hypertension, and dyslipidemia, are known to be modifiable by changes in lifestyle.[1,4] These conditions are linked to dietary habits, which include nutritional quality and food consumption, and physical inactivity; therefore, they can be prevented through dietary and other lifestyle interventions.[5-8] Several previous studies showed significant associations between food consumption habits and CVD or mild cognitive impairment in older Korean adults.[9-13] Meal habits are highly dependent on social, cultural, and psychological determinants, as people integrate meals with their everyday life routines.[14,15] Meal habits are a factor that influences body weight and metabolic status.[14-20] Fabry et al.[14] suggested that meal frequency was negatively correlated with weight gain. Several studies have shown that irregular dietary intake was associated with unfavorable cardiometabolic health markers, including obesity, type 2 DM, and dyslipidemia.[16,18] An animal study demonstrated that eating at the "wrong time" could lead to weight gain in mice, even though all the mice ate the same amount of energy.[21] Specifically, mice fed a high-fat diet only during the dark phase showed significantly higher weight gain than mice fed only during the light phase.[21] Breakfast consumption has shown significant associations with CVD health, because it is associated with factors such as satiety, total energy intake, metabolic efficiency of the diet, and appetite regulation.[22-24] It was reported that feeding and fasting-entrained clock genes regulating all aspects of metabolism, and especially dietary habits related to meal timing, can have serious implications for the development of cardiometabolic disorders.[17,25] In human studies, the changes associated with a delayed eating time contributed to obesity among breakfast skippers or patients with night-eating syndrome.[26,27] Several National Health and Nutrition Examination Survey (NHANES) studies have shown that eating breakfast was associated with a lower body mass index (BMI) compared with skipping breakfast, among both adults and young children.[28,29] Several cross-sectional studies have reported that breakfast consumers tended to have a lower BMI than breakfast skippers, and that obese individuals were more likely to skip breakfast or to consume less food at breakfast.[18] Furthermore, breakfast consumption was inversely associated with the risk of a 5-kg weight gain among males in the United States.[28,30,31]

Therefore, we investigated whether breakfast consumption and meal time regularity were associated with nutrient intake and cardiometabolic health status in Korean adults, thereby providing the basis for an optimal dietary behavioral guideline favorable for cardiometabolic health.

MATERIALS AND METHODS

1. Study subjects and design

Study participants (age ≥19 years old) were recruited through a public advertisement. We excluded individuals with any diagnosed chronic disease such as diabetes, CVD, stroke, cancer, and coronary heart disease or other metabolic diseases including thyroid, renal, vascular, and liver disorders, and those taking antihypertensive, lipid-lowering, antidiabetic or antithrombotic medications. Among the recruited individuals, 217 were finally included in the analyses. The aim of the study was explained to the participants, who provided written

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informed consent for the use of their data. The study was approved by the Institutional Review Board of Dong-A University (project identification code: 2-104709-AB-N-01-201603-BR-001-10).

2. Diet survey and nutrient intake

The diet survey was conducted by a registered dietitian through face-to-face interviews. It consisted of questions about dietary habits, including breakfast consumption frequency (6–7 times/week, 2–5 times/week and 0–1 times/week) and meal time regularity (regular eating and irregular eating), a 3-day diet record using the 24-hour recall method (2 weekdays and 1 weekend), and a semi-quantitative food frequency questionnaire composed of 34 questions modified from the Korean NHANES form. The caloric intake and nutrient content from the 3-day diet record were estimated using the Computer Aided Nutritional analysis program (CAN-pro4.0; Korean Nutrition Society, Seoul, Korea). The intake levels of energy and nutrients were evaluated using the 2020 dietary reference intakes for Koreans. Inadequate nutrient intake was defined as nutrient intake less than the age- and sex-specific estimated average requirement. Inadequate intake of energy was defined as less than 75% of the age- and sex-specific estimated energy requirements for Koreans. Total energy expenditure (TEE, kcal/day) was calculated from activity patterns, including the basal metabolic rate and physical activity over 24 hours, and considering the thermic effect of food. Responses for breakfast consumption frequency were categorized into 6–7 times/week (n=105), 2–5 times/week (n=50) and 0–1 times/week (n=62), and those for meal time regularity were categorized into regular eating (n=126) and irregular eating (n=91). Considering the statistical power for the number of subjects in each subgroup according to their dietary habits (breakfast consumption and meal time regularity), the study population was finally subdivided into 4 groups according to breakfast consumption frequency (≥6 or <6 times/week) and meal time regularity (regular or irregular eating): breakfast ≥6 times/week and regular eating (HBRE, n=85); breakfast ≥6 times/week and irregular eating (HBIE, n=20); breakfast <6 times/week and regular eating (LBRE, n=41); and breakfast <6 times/week and irregular eating (LBIE, n=71).

3. Anthropometric parameters, blood pressure (BP), and blood collection

Height and weight were measured with each participant wearing light clothes except shoes. BMI was calculated as body weight divided by height in square meters (kg/m^2). Waist circumference was measured at the umbilicus with subjects standing after normal exhalation. The systolic and diastolic BPs were measured from the arm (left or right) of the person in the seated position using an automatic BP monitor (HEM-7220; Omron Healthcare Co., Ltd., Matsusaka, Japan), after 20 minutes of rest. Blood samples were collected in both plain and ethylenediaminetetraacetic acid-treated tubes in the morning after an overnight fast. The samples were centrifuged at 1,300 ×*g* for 15 minutes for plasma collection and at 2 000 ×*g* for 15 minutes for serum collection, both at ambient temperatures, and then stored at −80°C before analysis.

4. Glycemic parameters, lipid profile, and inflammation markers

Blood fasting glucose levels were determined by the glucose oxidase method with a Beckman Glucose Analyzer (Beckman Instruments, Irvine, CA, USA). Glycated hemoglobin (Hb_{A1c}) was measured using a VARIANT II Turbo HbA1C kit-2.0 (Bio-Rad, Hercules, CA, USA). Insulin and C-peptide levels were measured by radioimmunoassays using commercial kits (ImmunoNucleo Corporation, Stillwater, MN, USA). Insulin resistance (IR) was calculated with the homeostatic model assessment (HOMA) using the following equation:

$$\text{HOMA-IR} = \{\text{Fasting Insulin } (\mu IU/mL) \times \text{Fasting Glucose } (mg/dL)\}/450.$$

Serum triglyceride, total cholesterol, and low-density lipoprotein (LDL)-cholesterol levels were measured by enzymatic assays using commercially available kits on a Hitachi 7150 Autoanalyzer (Hitachi Ltd., Tokyo, Japan). After precipitation of chylomicrons with dextran sulfate magnesium, the levels of high-density lipoprotein (HDL)-C in the supernatant were analyzed by an enzymatic method. The serum level of high-sensitivity C-reactive protein (hs-CRP) was measured with an ADVIA 1650 system (Bayer Healthcare, Tarrytown, NY, USA) using a commercially available, high-sensitivity CRP-Latex (II) × 2 Kit (Seiken Laboratories Ltd., Tokyo, Japan).

5. Statistical analysis

Statistical analyses were performed using SPSS version 25.0 for Windows (IBM Corp., Armonk, NY, USA). One-way analysis of variance with the Bonferroni correction was used for continuous variables, and a general linear model with adjustment for confounding factors and the χ^2 test for frequency were used to evaluate differences among the 4 groups. Skewed variables were log-transformed for statistical analysis. For descriptive purposes, the mean values are presented using untransformed values. The results were expressed as means±standard errors, or percentages. A 2-tailed *P*-value of less than 0.05 was considered to indicate statistical significance.

RESULTS

1. General characteristics of the study participants according to their dietary habits

As explained above, the study participants were subdivided into 4 groups according to their dietary habits of breakfast consumption frequency and meal time regularity: HBRE (breakfast ≥6 times/week and regular eating, n=85), HBIE (breakfast ≥6 times/week and irregular eating, n=20), LBRE (breakfast <6 times/week and regular eating, n=41) and LBIE (breakfast <6 times/week and irregular eating, n=71). **Table 1** presents general characteristics and anthropometric parameters among the 4 groups. The LBIE group was significantly younger and heavier (higher BMI and waist circumference) than the HBRE group. However, the proportions of sex, cigarette smoking and alcohol drinking habits, physical activity (regular exercise), and the levels of systolic and diastolic BP were not significantly different among the 4 groups.

Table 1. Demographic, lifestyle, and anthropometric parameters according to breakfast consumption frequency and meal time regularity

Characteristics	HBRE (n=85)	HBIE (n=20)	LBRE (n=41)	LBIE (n=71)
Age (yr)	48.9±1.1[a]	43.4±3.1[b]	42.8±1.7[b]	36.0±1.4[c]
Male	20 (23.5)	3 (15.0)	10 (24.4)	23 (32.4)
Regular exercise	32 (39.5)	7 (35.0)	15 (36.6)	28 (39.4)
Current smoking	8 (9.4)	0	4 (9.8)	2 (2.9)
Current drinking	48 (57.6)	14 (73.7)	26 (63.4)	54 (76.1)
BMI (kg/m^2)	23.3±0.4[b]	23.8±0.7[ab]	23.3±0.5[ab]	24.4±0.4[a]
Waist circumference (cm)	78.9±1.1[b]	82.0±2.3[ab]	79.3±1.7[ab]	84.0±1.3[a]
Systolic BP (mmHg)	115.1±1.3	116.0±3.0	115.2±2.4	118.3±1.9
Diastolic BP (mmHg)	73.5±0.9	74.6±1.9	72.7±1.5	76.1±1.4

Data are means±standard error or number (%), and were tested using 1-way analysis of variance with the Bonferroni correction or the χ^2 test.
HBRE, breakfast ≥6 times/week and regular eating; HBIE, breakfast ≥6 times/week and irregular eating; LBRE, breakfast <6 times/week and regular eating; LBIE, breakfast <6 times/week and irregular eating; BP, blood pressure; BMI, body mass index.
[a-c]Values sharing the same alphabetical letter have no statistically significant differences.

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Table 2. Biochemical parameters according to breakfast consumption frequency and meal time regularity

Parameters	HBRE (n=85)	HBIE (n=20)	LBRE (n=41)	LBIE (n=71)
Glucose (mg/dL)*	94.1±2.0^{a}	83.9±1.7^{b}	89.7±2.4^{ab}	91.1±1.9^{ab}
Hb_{A1c} (%)†	5.52±0.1^{a}	5.27±0.1^{ab}	5.40±0.1^{ab}	5.34±0.1^{b}
Insulin (μIU/mL)	10.1±1.7	11.7±3.6	9.15±1.8	13.8±2.1
C-Peptide (ng/dL)*	1.92±0.3^{b}	2.45±0.5^{ab}	2.34±0.4^{ab}	2.58±0.2^{a}
HOMA-IR	1.59±0.4^{b}	2.03±0.7^{ab}	1.58±0.5^{a}	3.14±0.6^{a}
Triglyceride (mg/dL)*	97.4±6.2	90.1±16.6	95.5±11.0	109.1±9.9
HDL-cholesterol (mg/dL)	62.3±1.6	60.8±3.9	61.6±2.6	60.0±1.8
LDL-cholesterol (mg/dL)*	122.1±3.4	115.0±6.7	115.2±5.0	119.2±3.5
Total cholesterol (mg/dL)	193.8±3.7	187.5±6.5	185.7±5.1	193.6±4.0
hs-CRP (mg/dL)*	0.59±0.2^{b}	0.59±0.2^{ab}	1.00±0.3^{ab}	1.59±0.6^{a}

Data are means±standard error.
HBRE, breakfast ≥6 times/week and regular eating; HBIE, breakfast ≥6 times/week and irregular eating; LBRE, breakfast <6 times/week and regular eating; LBIE, breakfast <6 times/week and irregular eating; Hb_{A1c}, hemoglobin A1c; HOMA-IR, homeostatic model assessment of insulin resistance; HDL, high-density lipoprotein; LDL, low-density lipoprotein; hs-CRP, high-sensitivity C-reactive protein.
^{a,b}Values sharing the same alphabetical letter have no statistically significant differences. *Data were tested after being log-transformed. †Data were tested using 1-way analysis of variance with the Bonferroni correction or the χ^2 test.

2. Glycemic parameters, lipid profiles, and inflammation markers according to participants' dietary habits

Table 2 shows biochemical parameters among the 4 groups. Fasting glucose levels and Hb_{A1c} (%) were significantly higher in the HBRE group than in the HBIE group and the LBIE group, respectively, but all the mean values among the groups were within the normal range. HOMA-IR, C-peptide levels, and hs-CRP were significantly lower in the HBRE group than in the LBIE group. Fasting levels of insulin, triglyceride, HDL-cholesterol, and LDL-cholesterol were not significantly different among the 4 groups.

3. Daily nutrient intake according to participants' dietary habits

Fig. 1 presents daily nutrient intake according to dietary habits. The TEE and TCI were significantly higher in the LBIE group than in the higher breakfast consumption (HBRE, HBIE) groups and the LBRE group (**Fig. 1A**). The proportion of energy intake derived from carbohydrates was significantly higher, but that from fats was lower in the HBRE group than in the LBRE and LBIE groups (**Fig. 1B**). In addition, the LBRE and LBIE groups had significantly lower proportions of energy intake (relative to the TCI) at breakfast and higher proportions of energy intake at dinner than the HBRE group (**Fig. 1C**). Micronutrient intake

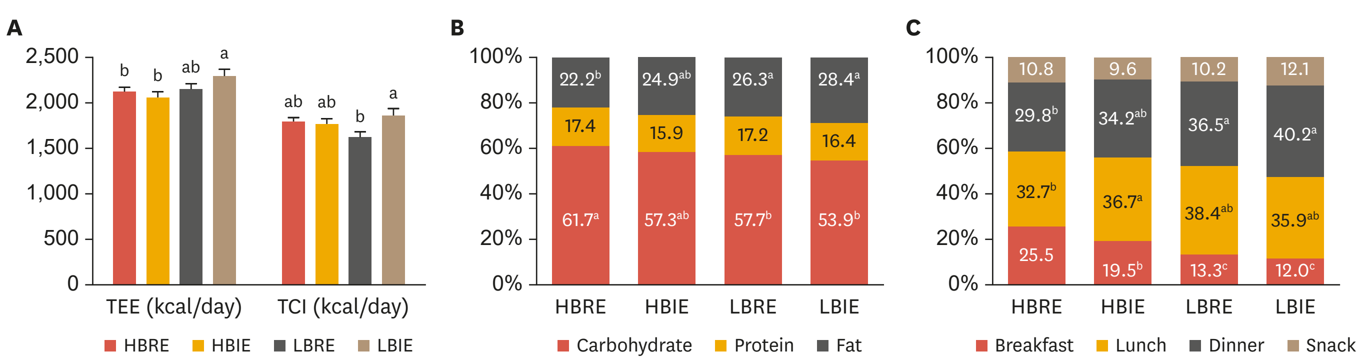

Fig. 1. Caloric intake according to breakfast consumption frequency and meal time regularity.
(A) Total energy expenditure and total caloric intake per day. (B) Proportions of caloric intake derived from macronutrients. (C) Proportion of caloric intake according to meal period. *P*-values were obtained using 1-way analysis of variance with the Bonferroni correction.
TEE, total energy expenditure; TCI, total caloric intake; HBRE, breakfast ≥6 times/week and regular eating; HBIE, breakfast ≥6 times/week and irregular eating; LBRE, breakfast <6 times/week and regular eating; LBIE, breakfast <6 times/week and irregular eating.
^{a,b}Values sharing the same alphabetical letter have no statistically significant differences.

was also significantly different among the 4 groups when controlling for age, sex, BMI, cigarette smoking and alcohol drinking habits, and/or TCI (**Fig. 2**). Participants who had regular meal timing, particularly those with breakfast consumption ≥6 times/week, generally consumed higher amounts of micronutrients than those who had irregular meal timing, but the amount of cholesterol intake was not significantly different among the 4 groups. The proportions of participants with inadequate nutrient intake according to their dietary habits are presented in **Fig. 3**. The percentages of participants with inadequate nutrient intake were generally higher in the groups with less frequent breakfast consumption than in the HBRE group. In particular, the percentage of participants with an inadequate intake of energy, protein, vitamins such as vitamin A, vitamin C, vitamin B6, folate, and vitamin B12, and minerals such as iron, zinc, and copper, were significantly higher in the LBIE group than in the HBRE group. However, all 4 groups showed substantial proportions of participants with an inadequate intake of magnesium (over 90%) and calcium (50%).

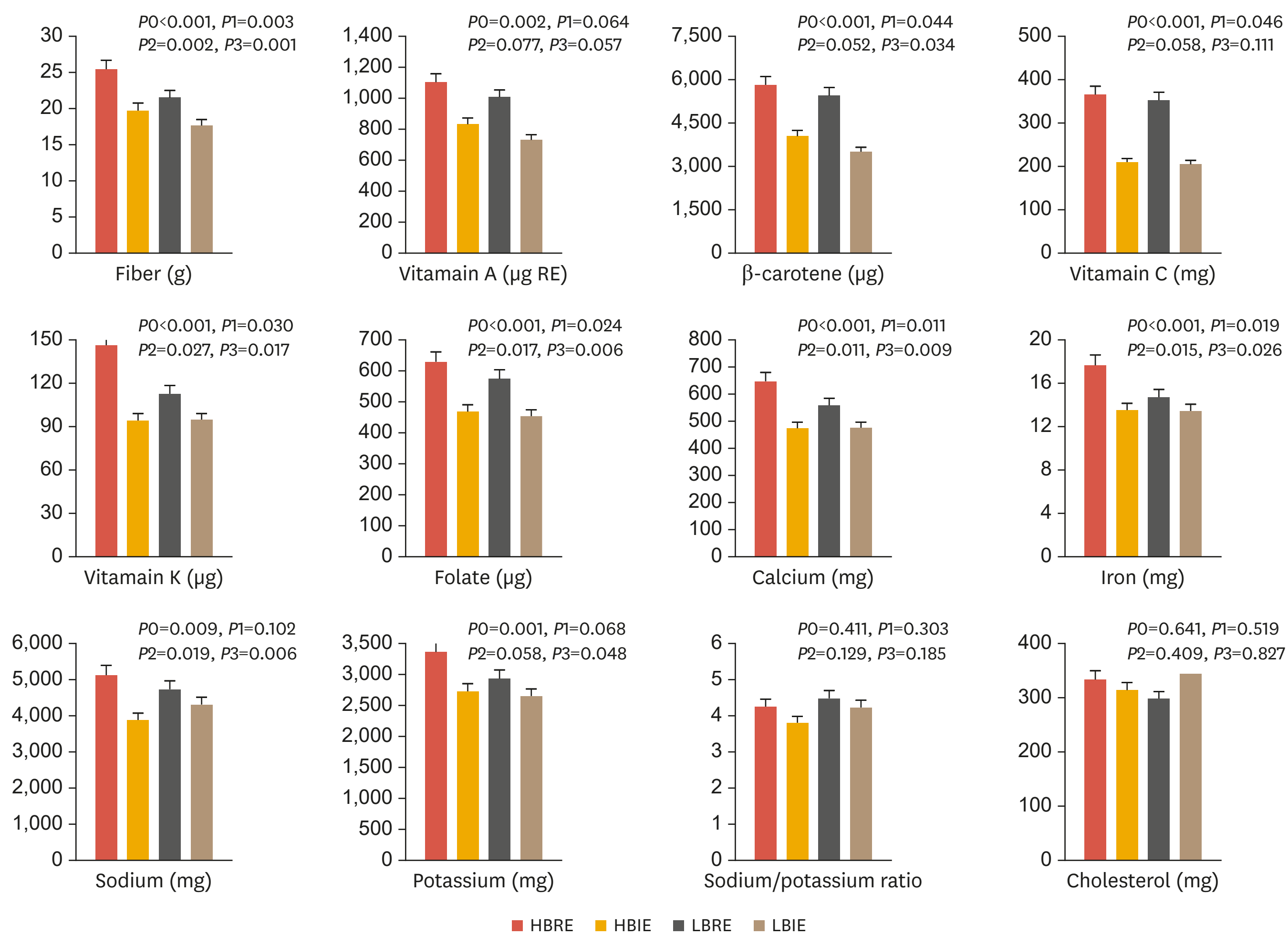

Fig. 2. Daily nutrient intake amounts according to breakfast consumption frequency and meal time regularity.
P-values were obtained using 1-way analysis of variance with the Bonferroni correction or general linear model analysis with adjustment for confounding factors. *P*0 indicates the unadjusted *P*-value; *P*1 indicates the *P*-value adjusted for age, sex, and BMI; *P*2 indicates the *P*-value adjusted for age, sex, BMI, cigarette smoking, and alcohol drinking; *P*3 indicates *P*-value adjusted for age, sex, BMI, cigarette smoking, alcohol drinking, and total caloric intake.
BMI, body mass index; HBRE, breakfast ≥6 times/week and regular eating; HBIE, breakfast ≥6 times/week and irregular eating; LBRE, breakfast <6 times/week and regular eating; LBIE, breakfast <6 times/week and irregular eating; RE, retinol equivalents.

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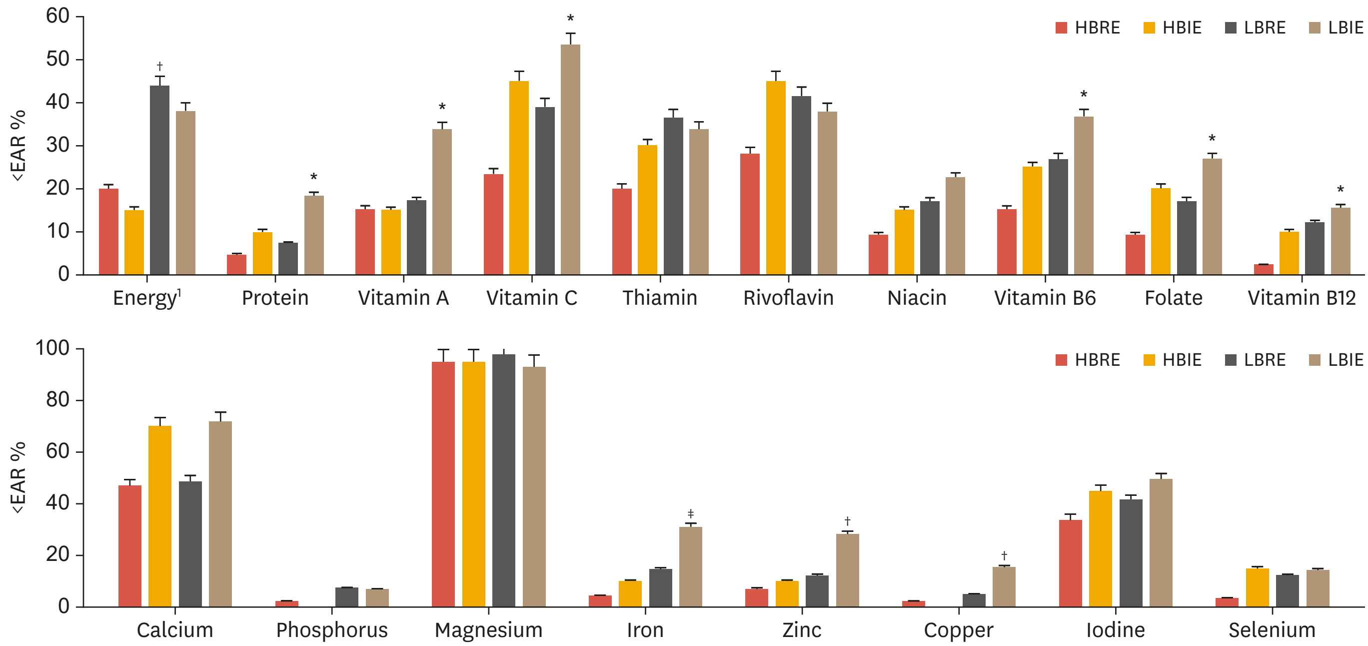

Fig. 3. The proportions of inadequate nutrient intake according to breakfast consumption frequency and meal time regularity.
Data are percentages (%). *P*-values were obtained using the χ^2 test. Inadequate intake was defined as nutrient intake less than the sex- and age-specific estimated average requirement for Koreans.[1] Inadequate intake was defined as energy intake less than 75% of the sex- and age-specific estimated energy requirement for Koreans.
HBRE: breakfast ≥6 times/week and regular eating, HBIE, breakfast ≥6 times/week and irregular eating; LBRE, breakfast <6 times/week and regular eating; LBIE, breakfast <6 times/week and irregular eating; EAR, estimated average requirement.
$^*P<0.05$, $^\dagger P<0.01$, $^\ddagger P<0.001$ compared with the HBRE group.

DISCUSSION

The aim of this study was to investigate whether breakfast consumption frequency and meal time regularity affected nutrient intake and cardiometabolic status in Korean adults. We found that less frequent breakfast consumers, particularly those with irregular meal eating, were proportionally more likely to have inadequate nutrient intake, were more likely to be obese, and had higher levels of glycated hemoglobin, C-peptide, HOMA-IR, and inflammation status in comparison with participants who ate breakfast almost every day and had regular meal timing. These results may indicate that the regularity of breakfast consumption and meal times are closely related to healthy lifestyle habits and play an important role in providing adequate nutrients, thereby affecting metabolic health status. Based on this study, we suggest that it is important for Korean adults to have regular breakfast consumption and meal times to prevent obesity and to maintain cardiometabolic health.

Our results are partly supported by previous reports.[14,18,20,26,27] In an earlier study, breakfast skippers were more likely to be obese and have metabolic syndrome than regular breakfast eaters,[20] and low meal frequencies were associated with weight gain.[14] A 10-year follow-up study also suggested that breakfast consumption is beneficial for the prevention of weight gain compared with breakfast skipping in middle-aged and older men by showing that men who consumed breakfast had a 23% lower risk of a 5-kg weight gain than those who did not.[18] In addition, eating at delayed or incorrect times can contribute to obesity, as observed in breakfast skippers or patients with night-eating syndrome.[26,27]

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According to the report by Farshchi et al.,[32] breakfast skippers had higher levels of total cholesterol and LDL-cholesterol at fasting states than those who ate breakfast, and regular breakfast consumers had relatively lower levels of total cholesterol, LDL-cholesterol, and triglyceride together with a reduced postprandial insulin response, which may substantially reduce the risk of CVD development. Our study also found that fasting levels of C-peptide and HOMA-IR were significantly lower in participants who regularly consumed breakfast (≥6 times/week) and regularly ate meals than those who consumed breakfast less frequently and had an irregular meal eating pattern, but the lipid profiles were not significantly different among the groups. The discrepancy between our study and others may be due to differences in the characteristics of study participants. For example, our study participants had not been diagnosed with chronic diseases, meaning that they might have had healthier metabolic conditions than people in other studies. In addition, our study showed that fasting hs-CRP levels in the LBIE group were significantly higher than in the HBRE and HBIE groups. Increased inflammation was associated with an increased intake of dietary fats, particularly saturated fats.[33] High-fat intake alters intestinal permeability, leading to an increase of lipopolysaccharides in the bloodstream, thereby exacerbating inflammatory responses.[34-36] Conversely, higher intake or status of antioxidants (*e.g.*, antioxidant vitamins, minerals, and enzymes) may reduce the inflammatory response by eliminating reactive oxygen species.[37,38]

A possible mechanism of how regular breakfast consumption modestly contributes to the reduction of cardiometabolic risk relates to its potential impact on overall diet habits and nutrient composition.[24,39,40] Breakfast consumption was reported to be associated with the regulation of appetite, satiety, and total energy intake, and the metabolic efficiency of the diet.[22-24] According to a report by Jarvandi et al.,[23] a higher proportion of breakfast among one's daily meals was significantly associated with a lower daily TCI. Specifically, frequent and regular breakfast consumers had a higher intake of fiber, vitamins A, carotene, folate, vitamin C, vitamin K, calcium, and iron, and a lower intake of proteins, fats, and cholesterols, as well as TCI.[23] Similarly, many studies have indicated that consumption of breakfast contributes to an improved nutrient profile, and the frequency of breakfast consumption was independently associated with overall dietary intake adequacy or/and quality.[24,39,40] In our study, the HBRE group, who regularly consumed breakfast and had regular meals, had a higher proportion of energy intake at breakfast and a lower proportion at dinner, as well as a lower TCI, a higher intake of fiber and micronutrients (*e.g.*, beta-carotene, vitamin K, folate, calcium, and iron), and a lower prevalence of inadequate nutrient intake (*e.g.*, TCI, protein, vitamins such as vitamin A, vitamin C, vitamin B6, folate, and vitamin B12, and minerals such as iron, zinc, and copper) than the low-breakfast groups, particularly the LBIE group that consumed breakfast less frequently and had irregular meals.

However, a major limitation of this study is its cross-sectional design, which does not allow the identification of the causal effects of dietary habits on the development of cardiometabolic changes. In addition, dietary habits may be affected by age and sex, although this study adjusted for confounding factors including age and sex for the statistical analysis. Therefore, further studies with short-term and long-term observations including larger populations stratified by age and sex are needed. Despite the limitations of this study, these results indicate that regular breakfast consumption and meal times were closely related to healthy lifestyle habits and were important for providing adequate nutrients, which affects metabolic health status; therefore, ensuring regular breakfast consumption and regular meal times may help prevent obesity and related metabolic disorders.

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