Household-Specific Physical Activity Levels and Energy Intakes According to the Presence of Metabolic Syndrome in Korean Young Adults: Korean National Health and Nutrition Examination Survey 2016–2018

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Abstract

Background: Participation in exercise, and dietary and nutritional intakes have an impact on the risk and prevalence of metabolic syndrome (MetS), but these effects may differ according to whether a person lives alone or in a multi-person household. We analyzed differences in physical activity (PA) levels and energy intake according to household-type and MetS presence among young adults, to investigate the relationships among these factors.

Methods: Data of 3,974 young adults (aged > 19 years and < 40 years) were obtained from the Korean National Health and Nutrition Examination Survey (2016–2018). We analyzed PA levels (occupational and recreational PA, and place movement) and energy intake (total, carbohydrate, protein, and fat).

Results: Logistic regression data showed that low PA levels and higher energy intake were associated with MetS incidence and its components in young adults, after adjusting for body mass index, smoking, household-type, and sex. Overall, there was no significant difference in PA level between the MetS and non-MetS group. The total energy intake was higher in the MetS than in the non-MetS group ($p < 0.05$). These results were similar to those found in multi-person households. In single-person households, the MetS group had significantly lower PA levels ($p < 0.01$) and total energy intake ($p < 0.05$) than the non-MetS group.

Conclusions: We found significant association among low PA levels, high energy intake, and MetS components in young Korean adults, but with patterns differing according to household type. Energy intake was higher in young adults with than those without MetS, who lived in multi-person households, while young adults with MetS who lived alone had lower PA levels and lower energy intake than those without MetS. These findings highlight the need for different approaches of implementing PA and nutrition strategies according to the type of household in order to prevent MetS.

1. Introduction

The single-person household is the fastest growing type of household in many regions of the world, due to changes in institutional arrangements, demographic behaviors, and labor migration in the past few decades ¹. Not only widowed people, but also many young adults who have never been married, now live alone. The family structure in Korea has changed from the traditional large extended family to the nuclear family, due to industrialization and urbanization, and recently, the number of single-person households living alone in Korea has increased rapidly ². According to the National Statistical Office, the percentage of single-person households has increased from 15.5% in 2000, to 29.3% in 2018, and is estimated to reach 34.3% by 2035 ³.

According to the Korean National Health and Nutrition Examination Survey (KNHANES), the incidence of metabolic syndrome (MetS) has increased by 0.6% every 10 years since 1998 ⁴. Additionally, recent studies in Korea have found that single-person households are more susceptible than multi-person households to insufficient physical activity (PA) and unhealthy eating practices ⁵. The amount of PA has decreased, with a decrease in moderate PA and walking, without an increase in high-intensity PA ^{6,7}. Low levels of PA, in turn, contribute to the increase in MetS incidence.

In conjunction with social changes in Korea, the dietary behavior of Koreans has also changed rapidly. With increased aging of the Korean population and increasing numbers of single-person households, eating alone has become a social concern. Some previous studies reported that eating alone was associated with various health problems. Eating alone was related to a reduced calorie intake and a less-varied diet ^{8,9}, and it could be a direct risk factor for MetS ¹⁰.

The level of PA, the degree of participation in exercise, and dietary and nutritional intakes have an impact on the risk for and prevalence of MetS. In a recent comparative analysis, among 66,211 older individuals (aged 60 years or more) in Korea, single-person households are considered to have worse overall health behaviors, such as exercise behaviors and nutritional behaviors, than multi-person households ¹¹. According to KNHANES data (2013–2015) of 2,903 subjects $\geq$ aged 65 years, single-person households had worse nutrient intake overall, and had an increased prevalence of MetS ¹².

Research on housing and MetS of young people, particularly young single-person households, has been scant internationally. Moreover, there have been few studies about household type-specific PA and energy intake in young adults according to the presence of MetS. Thus, it is important to examine the relationship between these factors in a large population, and even

adequately-sized cohort studies evaluating PA levels and energy intakes according to household and the presence of MetS are not appropriate, because these factors vary according to young adults’ lifestyles and household types. Therefore, this study aimed to analyze the differences in PA levels and energy intake by household type and the presence of MetS in a young adult Korean population, based on data from the 7th Korea National Health and Nutrition Examination Survey (2016–2018).

2. Materials And Methods

2.1. Sample and Design

This study used cross-sectional data from the Korea National Health and Nutrition Examination Survey (KNHANES) from 2016 to 2018, which was conducted by the Korea Centers for Disease Control and Prevention (KCDC). The details of the study design and data resource profiles followed the methods described in the Guidelines for Use of the KNHANES Raw Data and the Final Report of the sampling frame¹³. The KNHANES consists of a health interview survey, a nutrition survey, and a health examination, and is conducted according to the Declaration of Helsinki. This survey was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (reference number: 2018-01-03-P-A). All participants in the survey signed an informed consent form.

Between 2016 and 2018, 24,269 individuals completed the health interview survey, nutrition survey, and health examination. Among them, 19,031 people aged under 20 years or more than 40 years were excluded, leaving 5,238 people between the ages of 20 years and 39 years. Participants previously diagnosed with cancer (gastric, liver, colon, breast, cervical, lung, thyroid, and other cancers), and those with missing data (anthropometric, health examination, and PA data) were excluded (Figure 1). In total, 3,974 young people were finally included in this study.

2.2. Measures

The presence or absence of MetS was determined using measurements of waist circumference, blood pressure, fasting blood glucose levels, triglyceride levels, and HDL-C levels. PA variables were evaluated using the Global Physical Activity Questionnaire (GPAQ), and PA was expressed in metabolic equivalents (MET)-minutes/week. Nutrient intake was also analyzed. The analyzed characteristics of the participants according to household are shown in Table 1.

Table 1
Descriptive characteristics of the participants

	Total (n=3,974)			Multi-person Households (n=3,619)			Single-person Households (n=355)		
	Non-MetS (n=3,477)	MetS (n=497)	p-Value	Non-MetS (n=3,169)	MetS (n=450)	p-Value	Non-MetS (n=308)	MetS (n=47)	p-Value
Age (years)	29.6±0.2	32.5±0.3	< 0.001***	29.7±0.2	32.7±0.3	< 0.001***	28.7±0.3	31.3±0.9	0.008**
Height (cm)	167.9±0.2	172.3±0.4	< 0.001***	167.7±0.2	172.1±0.4	< 0.001***	170.0±0.4	173.9±1.0	< 0.001***
Body weight (kg)	64.9±0.3	86.4±0.8	< 0.001***	64.6±0.3	85.7±0.9	< 0.001***	66.8±0.8	91.9±1.7	< 0.001***
BMI (kg/m ²)	22.9±0.1	29.0±0.2	< 0.001***	22.9±0.1	28.8±0.3	< 0.001***	23.0±0.3	30.3±0.5	< 0.001***
Alcohol (%)	67.7	72.3	0.105	66.5	71.1	0.131	77.7	82.2	0.469
Smoking (%)	21.8	39.5	< 0.001***	20.5	39.6	< 0.001***	32.9	38.9	0.516
Values are expressed as means standard errors; BMI, body mass index; MetS, metabolic syndrome. * <i>p</i> < 0.05, ** <i>p</i> < 0.01, *** <i>p</i> < 0.001.									

2.3. Metabolic Syndrome

The diagnosis of MetS was based on the new harmonized guidelines of the National Cholesterol Education Program-Adult Treatment Panel III and the American Heart Association and the National Heart Lung and Blood Institutes ^{14, 15}. For waist circumference, we followed the criteria suggested by the Korean Society for the Study of Obesity ¹⁶. If three or more of the following five criteria were met, participants were classified as having MetS: waist circumference > 90 cm (men) or > 85 cm (women); systolic blood pressure > 130 mmHg or diastolic blood pressure > 85 mmHg; fasting triglyceride (TG) levels > 150 mg/dL; fasting HDL-C levels < 40 mg/dL (men) or < 50 mg/dL (women); and fasting glucose levels > 100 mg/dL.

2.4. Physical Activity

The GPAQ comprises 16 questions grouped to capture PA undertaken in different behavioral domains: work, transport, and discretionary (also known as leisure or recreational) activities. It analyzes five domains of PA: vigorous-intensity work, moderate-intensity work, place movement, vigorous-intensity recreation, and moderate-intensity recreation. The World Health Organization (WHO) GPAQ analysis guidelines were used to analyze GPAQ data ¹⁷. We estimated that, compared to while sitting quietly, a person's caloric consumption was four times higher when they were being moderately active and eight times higher when they were being vigorously active. Therefore, when calculating the total energy consumption of an individual using GPAQ data, four METs were allocated to the time spent in moderate activity and eight METs to the time spent in vigorous activity, and the details are as follows:

- Vigorous intensity activity: occupational (MET) = $8.0 \times \text{vigorous intensity physical activity (day/week)} \times 1\text{-day vigorous intensity physical activity (minutes/day)}$
- Moderate intensity activity: occupational (MET) = $4.0 \times \text{moderate intensity physical activity (day/week)} \times 1\text{-day moderate intensity physical activity (minutes/day)}$
- Vigorous intensity activity: recreational (MET) = $8.0 \times \text{vigorous intensity physical activity (day/week)} \times 1\text{-day vigorous intensity physical activity (minutes/day)}$
- Moderate intensity activity: recreational (MET) = $4.0 \times \text{moderate intensity physical activity (day/week)} \times 1\text{-day moderate intensity physical activity (minutes/day)}$
- Place movement (MET) = $4.0 \times \text{place movement physical activity (day/week)} \times 1\text{-day place movement physical activity (minutes/day)}$
- Total Physical Activity (MET) = vigorous intensity activity: occupational + moderate intensity activity: occupational + vigorous intensity activity: recreational + moderate intensity activity: recreational + place movement.

PA levels were classified into four groups: inactive (0–249 MET min/week), somewhat active (250–499 MET min/week), active (500–999 MET min/week), and very active (>1000 MET min/week). These cut-off points are based on their equivalence to the following PA thresholds: 250 MET min/week represents an energy expenditure dose equivalent to half of threshold; 500 MET min/week is equivalent to the minimal threshold; and 1000 MET min/week is equivalent to twice the minimal threshold.

2.5. Energy Intake

The nutrition survey of the KNHANES consisted of a survey of dietary habits, 1-day 24-hour recall, and food frequency questionnaire administration. The nutrition survey data were collected by trained dietitians in the homes of the participants 1 week after the health interview and health examination. The daily energy intake was calculated using the Korean Foods and Nutrients Database of the Rural Development Administration. The following items were included in the analyses: total energy intake, carbohydrate intake, protein intake, and fat intake. Energy intake was categorized by dividing the ratio with estimated energy requirement (EER). Values less than 20% EER (< 0.8) were considered as lower intake, whereas values above 1.2 as higher intake.

2.6. Statistical Analysis

Continuous variables were presented as means and standard errors. Normality of the distribution of all outcome-variable data was verified using the Kolmogorov–Smirnov test. An independent *t*-test was used to analyze risk factors for MetS, as well as PA levels and energy intakes between the non-MetS and MetS group. Two-way analyses of variance (ANOVA) were used to analyze the differences in risk factors for MetS, PA levels, energy intakes between participants with and without MetS, and between single-person and multi-person households. Partial eta-squared (η^2) values were calculated to represent effect sizes. If a significant

interaction effect was found by two-way ANOVA, a Bonferroni post-hoc test was used to compare the household-specificity of dependent variables in each group (with and without MetS) separately. Moreover, the relationships between PA levels or energy intake and MetS were determined using logistic regression analysis after controlling for covariates. Logistic regression analysis findings were presented as odds ratios (ORs) and their associated 95% confidence intervals (CIs). Statistical analyses were performed using SPSS version 25.0 for Windows (IBM Corp., Armonk, NY, USA). The level of significance was set at 0.05.

3. Results

The average values of PA levels and energy intake factors are shown in Table 2 and the ORs for MetS and MetS components according to PA levels and energy intake are presented in Table 3. The ORs were adjusted for body mass index, smoking, household-type, and sex in model 2. We found that an “Active” PA level was associated with low HDL-C levels (OR = 0.76, 95%CI = 0.61–0.93). A PA level of “Very active” was associated with a lower MetS incidence (OR = 0.55, 95%CI = 0.39–0.77), larger waist circumference (OR = 0.64, 95%CI = 0.43–0.93), high triglyceride (TG) levels (OR = 0.69, 95%CI = 0.56–0.87), and low levels of high-density lipoprotein C (HDL-C) (OR = 0.72, 95%CI = 0.59–0.88). We also found that “Moderate energy intake” levels were associated with a larger waist circumference (OR = 1.46, 95%CI = 1.05–2.04) and high glucose levels (OR = 1.23, 95%CI = 1.02–1.63). “Higher energy intake” levels were associated with the high TG levels (OR = 1.33, 95%CI = 1.03–1.70), low HDL-C levels (OR = 0.77, 95%CI = 0.61–0.97), and high glucose levels (OR = 1.39, 95%CI = 1.01–1.92).

Table 2
Classification of physical activity levels and energy intake

Factors	Total	n	Multi-person Households	n	Single-person Households	n
Physical activity factors	MET min/Week (Mean±SE)					
Inactive	39.6±2.5	1354	40.0±2.6	1255	35.4±7.6	99
Somewhat active	406.9±3.2	464	406.1±3.3	428	415.9±11.3	36
Active	750.7±5.3	834	752.5±5.8	746	739.2±12.5	88
Very active	2775.1±100.2	1322	2754.4±97.8	1190	2944.4±345.2	132
Energy intake factors	Energy intake/EER (Mean±SE)					
Lower energy intake (energy intake/EER<0.8)	0.6±0.0	2067	0.6±0.0	1884	0.5±0.0	183
Moderate energy intake (0.8≤energy intake/EER≤1.2)	1.0±0.0	1288	1.0±0.0	1163	1.0±0.0	125
Higher energy intake (energy intake/EER>1.2)	1.5±0.0	619	1.5±0.0	572	1.4±0.0	47
Values are expressed as means ± standard errors. EER = estimated energy requirements						

Table 3
Odds ratio (95% CI) for MetS and MetS components according to physical activity levels and energy intake

Factors	MetS	Large Waist Circumference	High Triglycerides	Low HDL-C	High Blood Pressure	High Glucose
Model 1 ¹⁾						
Physical activity factors						
Inactive (n=1354)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Somewhat active (n=464)	0.79 (0.54-1.16)	0.89 (0.64-1.23)	0.69 (0.51-0.94)*	0.80 (0.59-1.09)	0.71 (0.48-1.05)	0.84 (0.57-1.24)
Active (n=834)	0.86 (0.64-1.16)	0.927 (0.711-1.207)	0.78 (0.62-0.97)*	0.77 (0.63-0.94)*	1.10 (0.83-1.46)	0.99 (0.72-1.35)
Very active (n=1322)	0.84 (0.63-1.12)	1.02 (0.81-1.29)	0.88 (0.72-1.08)	0.74 (0.61-0.89)**	1.15 (0.89-1.49)	0.96 (0.75-1.22)
Energy intake factors						
Lower energy intake (energy intake/EER<0.8)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Moderate energy intake (0.8≤energy intake/EER≤1.2)	0.85 (0.66-1.10)	0.77 (0.63-0.93)**	0.92 (0.74-1.14)	0.90 (0.76-1.07)	0.90 (0.73-1.12)	1.07 (0.84-1.36)
Higher energy intake (energy intake/EER>1.2)	0.84 (0.62-1.13)	0.77 (0.58-1.02)	1.16 (0.93-1.46)	0.68 (0.54-0.85)**	0.86 (0.64-1.15)	1.16 (0.86-1.55)
Model 2 ²⁾						
Physical activity factors						
Inactive (n=1354)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Somewhat active (n=464)	0.91 (0.58-1.41)	1.10 (0.68-1.80)	0.75 (0.53-1.06)	0.80 (0.58-1.11)	0.77 (0.51-1.18)	0.92 (0.62-1.36)
Active (n=834)	0.86 (0.59-1.24)	1.05 (0.65-1.70)	0.78 (0.60-1.01)	0.76 (0.61-0.93)**	1.12 (0.82-1.52)	1.01 (0.74-1.39)
Very active (n=1322)	0.55 (0.39-0.77)***	0.64 (0.43-0.93)*	0.69 (0.56-0.87)**	0.72 (0.59-0.88)**	0.90 (0.67-1.19)	0.81 (0.63-1.05)

Data presented as odds ratio (95% confidence intervals (CIs)). OR = odds ratio, MetS = metabolic syndrome, HDL-C = high-density lipoprotein cholesterol, EER = estimated energy requirements. * p < 0.05 vs. reference, ** p < 0.01 vs. reference, *** p < 0.001 vs. reference; ¹⁾ Model 1: crude. ²⁾ Model 2: adjusted for sex, smoking, household type, and body mass index.

Factors	MetS	Large Waist Circumference	High Triglycerides	Low HDL-C	High Blood Pressure	High Glucose
Energy intake factors						
Lower energy intake (energy intake/EER<0.8)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Moderate energy intake (0.8≤energy intake/EER≤1.2)	1.20 (0.88-1.64)	1.46 (1.05-2.04)*	1.05 (0.83-1.32)	1.02 (0.85-1.22)	1.07 (0.86-1.35)	1.23 (1.02-1.63)*
Higher energy intake (energy intake/EER>1.2)	1.19 (0.81-1.75)	1.58 (0.94-2.65)	1.33 (1.03-1.70)*	0.77 (0.61-0.97)*	1.01 (0.71-1.42)	1.39 (1.01-1.92)*
Data presented as odds ratio (95% confidence intervals (CIs)). OR = odds ratio, MetS = metabolic syndrome, HDL-C = high-density lipoprotein cholesterol, EER = estimated energy requirements. * p < 0.05 vs. reference, ** p < 0.01 vs. reference, *** p < 0.001 vs. reference; ¹⁾ Model 1: crude. ²⁾ Model 2: adjusted for sex, smoking, household type, and body mass index.						

The differences in variables considered risk factors for MetS, according to the presence or absence of MetS and according to households are presented in Table 4. In the total group, young individuals with MetS had significantly higher values of risk factors for MetS than did those in the non-MetS group (all variables, $p < 0.001$). The interaction between the presence or absence of MetS and household type (single- or multi-person) was statistically significant for waist circumference, TG, HDL-C, diastolic blood pressure (DBP), fasting blood glucose (all $p < 0.001$). The Bonferroni post-hoc test showed the following group differences: Individuals with MetS living in multi-person households had significantly larger waist circumference, TG, DBP, fasting blood glucose (all $p < 0.001$), but lower HDL-C ($p < 0.001$), than their counterparts without MetS. Individuals with MetS who lived alone had significantly larger waist circumference, TG, HDL-C, DBP, and fasting blood glucose than those without MetS (all $p < 0.001$). Individuals with MetS living as single persons had statistically significantly greater waist circumference and higher DBP (both $p < 0.01$) than individuals with MetS living in multi-person households.

Table 4
Metabolic Syndrome Components

Factors	Group	Total	Household type		ANOVA			
			Multiple	Single	F-value	<i>p</i> -Value (η²)	Power	
Waist circumference (cm)	Non-MetS	77.9±0.2	77.8±0.2	78.6±0.7	H	62.542***	0.000(0.006)	1.000
		95.63±0.5	95.2±0.6†	99.3±1.1†‡	M	1489.340***	0.000(0.068)	1.000
	MetS				H×M	87.608***	0.000(0.008)	1.000
	<i>p</i> -value	< 0.001***						
TG (mg/dL)	Non-MetS	102.8±1.7	102.2±1.9	107.8±2.9	H	2.390	0.092(0.000)	0.485
		242.7±9.5	243.5±9.9†	236.1±24.6†	M	748.808***	0.000(0.037)	1.000
	MetS				H×M	9.114***	0.000(0.001)	0.976
	<i>p</i> -value	< 0.001***						
HDL-C (mg/dL)	Non-MetS	54.9±0.3	55.0±0.2	53.8±0.9	H	0.022	0.978(0.000)	0.053
		40.9±0.4	40.7±0.4†	42.2±1.4†	M	552.453***	0.000(0.027)	1.000
	MetS				H×M	22.619***	0.000(0.002)	1.000
	<i>p</i> -value	< 0.001***						
SBP (mmHg)	Non-MetS	109.5±0.3	109.1±0.2	112.4±0.9	H	176.024***	0.000(0.017)	1.000
		123.0±0.6	122.6±0.7	125.9±2.3	M	451.997***	0.000(0.022)	1.000
	MetS				H×M	0.485	0.485(0.616)	0.130
	<i>p</i> -value	< 0.001***						
DBP (mmHg)	Non-MetS	72.6±0.2	72.4±0.2	74.8±0.6	H	43.256***	0.000(0.004)	1.000
		85.1±0.5	84.6±0.5†	88.6±1.4†‡	M	629.397***	0.000(0.030)	1.000
	MetS				H×M	61.583***	0.000(0.006)	1.000
	<i>p</i> -value	< 0.001***						
Fasting glucose (mg/dL)	Non-MetS	90.3±0.3	90.3±0.3	90.4±0.5	H	130.082***	0.000(0.013)	1.000
		108.0±1.5	108.5±1.6†	104.2±2.7†	M	359.141***	0.000(0.018)	1.000
	MetS				H×M	7.636***	0.000(0.001)	0.948
	<i>p</i> -value	< 0.001***						
Values are expressed as means standard errors; MetS, metabolic syndrome; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, glycated hemoglobin. Main effect = H (Household) and M (Metabolic syndrome), Interaction effect = H × M (Household × Metabolic syndrome), * <i>p</i> < 0.05, ** <i>p</i> < 0.01, *** <i>p</i> < 0.001, † <i>p</i> < 0.001 compared with Non-MetS values, ‡ <i>p</i> < 0.01 compared with Multiple values. Two-way analysis of variance following Bonferroni post-hoc test.								

The differences in PA levels according to the presence or absence of MetS and according to household type are presented in Table 5. In the total group, there was no significant difference in PA levels between young individuals with and without MetS. For the PA aspects of “Occupational vigorous” ($p < 0.05$), “Place movement” ($p < 0.5$), and “Total PA” ($p < 0.01$), there was a significant interaction between the presence or absence of MetS and household type. The Bonferroni post-hoc test showed the following group

differences: Individuals with MetS living in multi-person households showed significantly higher “Occupational vigorous” PA ($p < 0.05$) than their counterparts without MetS. Those with MetS who lived alone demonstrated significantly lower “Place movement” and “Total” PA (all $p < 0.01$) than their counterparts without MetS. There was no significant difference between those with MetS living in single-person households and those with MetS living in multi-person households.

Table 5
Levels of physical activity

Physical Activity (MET min/week)	Group	Total	Household type		ANOVA			
			Multiple	Single	F-value	<i>p</i> -Value (η ²)	Power	
Occupational vigorous	Non-MetS	76.7±15.5	65.1±12.8	176.0±86.9	H	3.765*	0.023(0.000)	0.689
		132.4±47.8	148.5±53.5†	1.7±1.7	M	0.836	0.361(0.000)	0.150
	MetS	0.271			H×M	4.575*	0.010(0.000)	0.778
	<i>p</i> -value							
Occupational moderate	Non-MetS	214.6±23.9	214.0±25.0	219.3±61.2	H	29.891***	0.000(0.003)	1.000
		234.7±45.5	251.8±51.0	95.6±45.8	M	0.850	0.357(0.000)	0.152
	MetS	0.688			H×M	1.621	0.198(0.000)	0.345
	<i>p</i> -value							
Place movement	Non-MetS	524.2±17.6	514.5±17.6	607.7±69.5	H	26.954***	0.000(0.003)	1.000
		474.2±43.9	490.2±48.1	344.0±70.6††	M	9.888**	0.002(0.000)	0.882
	MetS	0.253			H×M	3.559*	0.028(0.000)	0.663
	<i>p</i> -value							
Recreational vigorous	Non-MetS	212.9±17.0	209.3±17.4	243.5±42.6	H	30.567***	0.000(0.003)	1.000
		191.9±39.6	194.2±44.6	172.8±68.3	M	3.324	0.068(0.000)	0.446
	MetS	0.628			H×M	0.991	0.371(0.000)	0.224
	<i>p</i> -value							
Recreational moderate	Non-MetS	181.8±9.0	183.0±9.8	171.1±22.6	H	10.371***	0.000(0.001)	0.988
		149.7±23.2	147.1±23.8	171.4±55.2	M	1.648	0.199(0.000)	0.250
	MetS	0.206			H×M	0.243	0.784(0.000)	0.088
	<i>p</i> -value							
Total physical activity	Non-MetS	1210.2±48.5	1186.0±46.6	1417.7±168.0	H	64.415***	0.000(0.006)	1.000
		1182.9±105.8	1231.8±116.1	785.4±172.7††	M	9.312**	0.002(0.000)	0.862
	MetS	0.812			H×M	5.062**	0.006(0.000)	0.820
	<i>p</i> -value							
Values are expressed as means standard errors; MetS, metabolic syndrome. Main effect = H (Household) and M (Metabolic syndrome), Interaction effect = H × M (Household × Metabolic syndrome), * <i>p</i> < 0.05, ** <i>p</i> < 0.01, *** <i>p</i> < 0.001, † <i>p</i> < 0.05, †† <i>p</i> < 0.01 compared with Non-MetS values. Two-way analysis of variance following Bonferroni post-hoc test.								

Table 6 shows the differences in energy intake according to the presence or absence of MetS and according to household type. In the total group, young individuals with MetS had significantly higher energy intake than those without MetS (total energy intake and protein intake, $p < 0.001$; carbohydrate intake, $p < 0.05$). For “Total energy intake”, “Protein intake”, “Fat intake” (all $p < 0.001$), and for “Carbohydrate intake” ($p = 0.001$), there was a significant interaction between the presence or absence of MetS and household type. The Bonferroni post-hoc test showed the following group differences: Individuals with MetS living in multi-person households had significantly higher total energy intake, protein intake, fat intake (all $p < 0.001$), and carbohydrate intake ($p < 0.01$) than those without MetS who lived in multi-person households. Persons with MetS who lived as single persons had significantly lower total

energy intake ($p < 0.05$) and fat intake ($p < 0.01$) than those without MetS who lived alone. Those with MetS who lived alone had a significantly lower total energy intake and fat intake ($p < 0.01$) than those with MetS who lived in a multi-person household.

Table 6
Energy intake

Factors	Group	Total	Household type		ANOVA				
			Multiple	Single	F-value	<i>p</i> -Value (η ²)	Power		
Total energy intake (kcal)	Non-MetS	2149.0±19.4	2137.8±21.1	2250.1±56.5	H	102.233***	0.000(0.011)	1.000	
	MetS	2396.7±58.9	2443.6±67.9†††	2012.1±130.6†‡	M	0.200	0.654(0.000)	0.073	
		<i>p</i> -value	< 0.001***			H×M	28.101***	0.000(0.003)	1.000
Carbohydrate intake (kacI)	Non-MetS	1173.0±11.2	1170.8±12.2	1193.3±26.9	H	0.237	0.789(0.000)	0.087	
	MetS	1236.5±24.4	1244.0±26.2††	1174.9±85.8	M	0.252	0.616(0.000)	0.079	
		<i>p</i> -value	0.021*			H×M	7.335**	0.001(0.001)	0.939
Protein intake (kcal)	Non-MetS	324.5±3.8	323.4±4.2	334.4±9.2	H	160.606***	0.000(0.018)	1.000	
	MetS	362.4±9.8	367.1±11.2†††	323.5±23.3	M	0.886	0.347(0.000)	0.156	
		<i>p</i> -value	< 0.001***			H×M	25.2218***	0.000(0.003)	1.000
Fat intake (kcal)	Non-MetS	523.9±8.8	517.4±9.2	581.9±25.2	H	278.513***	0.000(0.030)	1.000	
	MetS	567.1±23.1	580.9±26.6†††	453.9±41.2††‡	M	7.183**	0.007(0.000)	0.764	
		<i>p</i> -value	0.090			H×M	30.312***	0.000(0.003)	1.000
Values are expressed as means standard errors; MetS, metabolic syndrome. Main effect = H (Household) and M (Metabolic syndrome), Interaction effect = H × M (Household × Metabolic syndrome), * <i>p</i> < 0.05, ** <i>p</i> < 0.01, *** <i>p</i> < 0.001, † <i>p</i> < 0.05, †† <i>p</i> < 0.01, ††† <i>p</i> < 0.001 compared with Non-MetS values, ‡ <i>p</i> < 0.01 compared with Multiple values. Two-way analysis of variance following Bonferroni post-hoc test.									

4. Discussion

This study investigated differences in PA levels and energy intake by household-type and the presence of MetS in a young adult Korean population, to understand the relationships among these factors. We found that components of MetS, such as a large waist circumference, hyperlipidemia, low HDL-C levels, and high fasting blood glucose levels, can be improved by higher PA levels (Very active: 2775.1 ± 100.2 MET min/week) as compared with inactivity (0–249 MET min/week). Low HDL-C levels could also be improved by increased PA levels (Active: 500–999 MET min/week) as compared with inactivity. In addition, hyperlipidemia, low HDL-C, and high glucose levels can be improved by lower energy intake ($0.8 < \text{EER}$) as compared with higher energy intake ($\text{EER} > 1.2$). Large waist circumference and high glucose were also improved in those with lower energy intake as compared with those with moderate energy intake ($0.8 \leq \text{EER} \leq 1.2$). In the total group, there was no significant difference between MetS and non-MetS groups in terms of PA levels. This result was similar to that in multi-person households, except for the “Occupational vigorous” category. However, in single-person households, the MetS group had lower levels of “Place movement” and “Total physical activity” than the non-MetS group. Investigating the differences in energy intake according to the presence or absence of MetS and according to household type showed that, in the total group, the MetS group had significantly higher total energy intake, carbohydrate intake, and protein intake levels than the non-MetS group. In multi-person households, the MetS group had significantly higher total energy intake, carbohydrate intake, fat intake, and protein intake than the non-MetS group. However, in single-person households, the MetS group had significantly lower total energy intake and fat intake than the non-MetS group. In

particular, individuals with MetS who lived in single-person households had lower total energy intake and fat intake than those with MetS who lived in multi-person households. Taken together, our results showed the need for different approaches of implementing PA and nutrition strategies according to household type in order to prevent MetS.

Our results contribute to emerging evidence that PA levels and energy intake are associated with MetS components^{18,19}. We found that the prevalence of MetS factors was significantly lower among those with “Very active” PA levels as compared to those with an “Inactive” PA level. Young adults who were very active had a 45% lower prevalence of MetS. Similar to our study, Sisson et al.²⁰ found that men and women with higher levels of sedentary behavior than physical activity in the US had a 66% higher prevalence of MetS. Those with moderate physical activity (75–180 min/day) had a 29% lower prevalence of MetS, according to data of 4,327 adults obtained in the NHANEX from 2007 to 2010²¹. Moreover, among 410 subjects, aged 18–74 years, subjects with heavy PA levels (based on the Lipid Research Clinics questionnaire) had a 40% lower prevalence of MetS than subjects with light PA levels²². Regular PA has been shown to increase HDL-C in a linear dose–response manner²³. In addition, intense PA levels could reduce triglyceride levels²³.

With respect to energy intake, we found that the MetS risk factors had significantly higher values in individuals with moderate or higher energy intake (vs. those with a lower energy intake). Those with a moderate energy intake had a 46% higher prevalence of having a large waist circumference and a 23% higher prevalence of having high fasting glucose levels. Moreover, those with a higher energy intake had a 33% higher prevalence of high triglyceride, 23% lower prevalence of low LDL-C, and 39% higher prevalence of high fasting glucose levels. Similar to our study, 7,081 men aged 30 years and older, who overate more than 4 times a week, had a 141% higher prevalence of MetS²⁴. According to the data from the 2007–2012 KNHANES, from 20,515 Korean adults, a high carbohydrate intake (380.8 ± 4.7 g) resulted in a 32% higher prevalence of elevated TG and a 32% higher prevalence of MetS in men, and a 26% higher prevalence of elevated TG and 31% higher prevalence of MetS in women²⁵. Moreover, according to a cross-sectional study (6,737 males and 8,845 females) from the 2008–2011 KNHANES, a high carbohydrate intake was associated with a higher prevalence of MetS in males, and a high carbohydrate intake combined with a low fat intake was associated with MetS in females¹⁹. In addition, according to a study of 3-year KNHANES data, from 2012 to 2014, the prevalence of MetS was positively correlated with carbohydrate intake in an adult population, as assessed by the 24-hour recall questionnaire²⁶. These findings confirm that MetS is driven largely by a high nutrient energy intake, particularly that derived from carbohydrates, as young individuals with MetS had a higher carbohydrate intake than those without MetS in this study.

We found that there was no significant difference in PA levels between those with and those without MetS in the total group. However, the MetS group had a higher total energy intake, carbohydrate intake, and protein intake than those without MetS. The prevalence of MetS has increased rapidly in Asia in recent years, and several studies have demonstrated stronger associations between dietary carbohydrate intake and metabolic disease^{27,28}. The 2007–2012 National Health and Nutrition Examination Survey studies showed that a high carbohydrate intake is associated with metabolic abnormalities (Ha et al., 2018). According to a cross-sectional study performed in 2018 (6,737 males and 8,845 females), the risk of MetS increased proportionally with the carbohydrate intake proportion²⁵. As Korean adults consume more carbohydrates than adults in other regions, stronger associations of dietary carbohydrate with MetS were observed in this study. In addition, studies on the Korean population and a meta-analysis of observational studies have revealed that total, red, and processed meat consumption is associated with a high risk of MetS²⁹. Additionally, in a review of epidemiological evidence, dietary protein appeared to increase the risk of MetS³⁰. Korean eating habits have changed from a traditional diet focused on vegetables to a western diet focused on meat in recent years. Taken together, MetS in young individuals is more likely to be linked to energy intake than to PA levels.

This study analyzed household-specific PA according to the presence or absence of MetS in young adults. There was no significant difference across PA categories in multi-person households except for the “Occupational vigorous” category. In contrast, place movement and total PA were significantly lower in the MetS group than in the non-MetS group in single-person households. Numerous studies in recent decades have shown that higher PA levels have a favorable impact on each of the MetS components^{31,32,33}. In a cross-sectional evaluation of PA and metabolic risk among individuals with a family history of type 2 diabetes, it was suggested that increasing the total amount of PA in sedentary and overweight individuals had beneficial effects on MetS risk³⁴. An analysis of MetS in Korean adults, identified MetS risk factors as a lack of walking and flexibility exercises in single-person households³⁵. Although living alone does not equate to a lack of a social network or support, social support is important for

engaging in healthy behaviors, including PA ^{36,37}. Support from family ³⁸ and friends ³⁹ has also been shown to correlate positively with PA. Single-person households without social support could promote a decrease in total PA, which can serve as a potential risk factor for an increased incidence of MetS.

This study also analyzed household-specific dietary intake according to the presence or absence of MetS in young adults. The total energy intake, carbohydrate intake, protein intake, and fat intake were significantly higher in the MetS group than in the non-MetS group in individuals living in multi-person households. In contrast, the total energy intake and fat intake were significantly lower in the MetS group than in the non-MetS group in individuals living in single-person households. Moreover, the total energy intake and fat intake were significantly lower in individuals with MetS who lived alone than in those with MetS who lived in multi-person households. Multi-person households presented a similar tendency to the total group in terms of energy intake: those with MetS tended to have a higher energy intake, as mentioned above, whereas those living alone presented the opposite tendency. According to the 2020 Dietary Reference Intakes for Koreans ⁴⁰, the recommended energy intake for men aged 19–49 is about 2,550 calories, and for women aged 19–49, it is about 1,950 calories. The single-person household data in this study represented both men and women. Thus, they consumed relatively lower amounts of energy than recommended by the guidelines, but were not at a deficient level. Thus, we cautiously speculate that MetS in young adults in single-person households is more likely to be linked to lower PA levels than to energy intake.

MetS is caused by lifestyle factors, such as PA, diet, and weight, and it is reported that the risk of MetS can be reduced by increasing PA levels and by engaging in balanced eating habits ^{41, 42, 43}. In this study, we found that there are household-specific aspects to the PA levels and energy intake according to the presence or absence of MetS in young adults. This information can be used as a basis for preparing countermeasures through education on PA and nutrition, and by providing nutrition guidance for young adults with MetS according to the household type. Such practical measures are urgently needed to reduce the incidence of MetS among young Korean adults.

This study's results should be interpreted with consideration of the following limitations. First, we evaluated young adults with MetS, but did not consider the timing of MetS development or the duration of MetS. Second, the amount of PA was not assessed using heart rate measurements or using an accelerometer, but was quantified based on survey findings, which are prone to errors. Third, this study reported simple differences without identifying the causality underlying the relationships between PA and nutrition. Finally, the data generated by using the 24-hour-recall may not represent long-term dietary habits. Twenty-four-hour recall is essentially a retrospective method of diet assessment, where an individual is interviewed about their food and beverage consumption during the previous day or the preceding 24 hours. However, a single 24-hour-recall may not be representative of the habitual diet at an individual level.

5. Conclusions

According to the ORs of MetS components, statistically significant associations were observed among low PA levels, high energy intake, and MetS components, including large waist circumference, high TG, low HDL-C, and high fasting glucose levels in young Korean adults. However, our results showed different patterns of associations, according to the household type. In multi-person households, there was no significant difference between individuals with and without MetS, although young adults with MetS had higher energy intake than without MetS. On the other hand, in single-person households, young adults with MetS had lower PA levels and lower energy intake than those without MetS. These findings highlight the need for different approaches of implementing PA and nutrition strategies according to the household type, in order to prevent MetS. Programs aimed at decreasing energy intake are necessary for multi-person households, while programs aimed at increasing PA levels and fat intake and balanced nutrition are needed for single-person households. Current trends to use personal devices, smartphones, activity trackers to measure physical activity, and applications to measure energy intake can provide innovative opportunities for researchers and healthcare providers to educate clients and intervene in new ways to promote healthy lifestyles.

6. Declarations

Acknowledgments:

This study analyzed the data provided by the Korean National Health and Nutrition Examination Survey 2016-2018, conducted by the Korea Centers for Disease Control and Prevention.

Author Contributions:

Conception and study design, Y.L., J.L., and J.P.; Statistical Analysis, Y.L., Y.P., and J.P.; Investigation, Y.L., and E.S., and Data Interpretation Y.L., and J.P.; Writing-Original Draft Preparation, Y.L., and J.P.; Writing-Review & Editing, Y.L., E.S., H.L., and J.P.; Supervision, J.P. All authors have read and approved the final manuscript.

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Availability of data and materials:

The dataset can be downloaded from Korea National Health and Nutrition Examination Survey website (<https://www.kdca.go.kr/index.es?sid=a3>)

Ethics approval and consent to participate:

The KNHANES consists of a health interview survey, a nutrition survey, and a health examination, and is conducted according to the Declaration of Helsinki. This survey was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (reference number: 2018-01-03-P-A). All participants in the survey signed an informed consent form.

Consent for publication:

Not applicable.

Competing interests:

The authors declare no conflict of interest.

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Figures

Figure 1

Flow diagram for the selection of study participants