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ORIGINAL RESEARCH

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Effects of physical activity type and sedentary time on metabolically healthy obesity and metabolically unhealthy normal weight Korean men

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Abstract

Obesity has become a global health challenge linked to morbidity and mortality associated with cardiovascular diseases. This study aimed to compare metabolic health indicators according to obesity phenotypes and examine prevalence according to physical activity (PA) and sedentary time in metabolically healthy obesity (MHO) and metabolically unhealthy normal weight (MUNW). Data were obtained from 3242 men participating in the 7th and 8th Korean National Health and Nutrition Examination Surveys. Participants were divided into four groups based on body phenotype and metabolic health status using obesity. Metabolic health was defined as metabolic syndrome. Representative statistical analyzes were one-way analysis of variance (ANOVA) and multiple logistic regression analysis. Compared with MUNW, the MHO had higher obesity, but systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting glucose (FG), hemoglobin A1c (HbA1c), triglycerides (TG), low density lipoprotein cholesterol (LDLC), and total cholesterol (TC) were significantly lower. In comparison between MHO and metabolically healthy normal weight (MHNW), the same health group, there were no significant differences in SBP, FG, HbA1c, and LDLC. The odds ratio of MUNW in the normal weight group was 1.8 times higher than that of the high group in the low leisure PA group. The group with high sedentary time increased the MUNW odds ratio by 1.5 times compared to the low group. Meanwhile, in the obesity group, the high leisure PA group showed a 1.4-fold increase in the MHO odds ratio compared to the low group. In addition, the low sedentary group showed a 1.6-fold increase in the MHO odds ratio compared to the high sedentary group. In conclusion, MHO had higher adiposity than MUNW, but the metabolic health index was better. Low PA and high sedentary time increased the risk of MUNW even in normal weight. Conversely, high PA and low sedentary time increased the likelihood of MHO in the obesity group.

Keywords

Metabolically healthy obesity; Metabolically unhealthy normal weight; Physical activity; Sedentary time; Metabolic syndrome

1. Introduction

Obesity is closely associated with an increased risk of early occurrence and increased mortality from ischemic heart disease, stroke, type 2 diabetes, hypertension, and atherosclerosis [1, 2]. Obesity threatens long-term cardiovascular health and is likely to be metabolically unhealthy. As the risk of obesity is widely recognized, researchers studying obesity and metabolic health have emphasized between metabolically unhealthy obesity (MUO) and metabolically healthy normal weight (MUNW) [3]. However, researchers have found that obesity and metabolic health do not necessarily relate. Despite being obese, some individuals may have glucose, insulin resistance, blood pressure (BP), and blood lipid levels within normal ranges. Persons with these characteristics are considered metabolically healthy obesity (MHO) [4]. According to a study in the United States, approximately 30–50% of obese individuals are classified as MHO [4], and a Korean study revealed that 10% of obese persons are MHO [5]. Conversely, approximately 25% of normal-weight individuals have metabolic diseases and are referred to as metabolically unhealthy normal-weight (MUNW) individuals [6]. The prevalence of MUNW was about 6.4%, and additionally, the prevalence of MUO and MUNW was 13.9% and 16.8%, respectively [7].

Studies so far do not completely explain the causes of MHO and MUNW. Predictable and likely risk factors seem particularly important, including unmodifiable factors such as genetics, age, race, physical inactivity, an unhealthy diet, and

smoking or alcohol consumption [8, 9]. Gómez-Zorita *et al*. [8] reported that the prevalence of MHO was higher in Oceania than in North America. Furthermore, in a study conducted on 13,748 men and 8628 women aged 18–85 years, the prevalence of MHO was higher in women than in men [10].

Although the causes of MHO and MUNW are unclear, it is known that increases in physical activity (PA), including exercise training and leisure activities, and decreases in sedentary time reduce the risk of obesity, metabolic risk, and cardiovascular disease [11]. High PA among obese people has been mentioned to be associated with MHO, but some studies have reported that PA does not affect MHO [12, 13]. Despite inconclusive results, the benefits of PA on metabolic health are well known. However, many studies have only compared the total amount of PA without evaluating PA by considering its intensity and type, such as moving place and occupational activity [14–16]. PA includes movement, occupational activity, home and leisure activities, and sports, and the World Health Organization (WHO) International Physical Activity Questionnaire (IPAQ) also does not differentiate between types of PA [17].

Therefore, this study aims to analyze the relationship between obesity phenotype and metabolic health-related clinical characteristics and examine in detail and comprehensively the prevalence of MUNW in the normal weight group and MHO in the obesity group according to the various PA characteristics and sedentary time.

2. Materials and methods

2.1 Participants

This study analyzed 3242 men (aged 20–79 years) from the 7th and 8th Korean National Health and Nutrition Examination Surveys. Conditions for inclusion or exclusion are shown in Fig. 1 diagram. Metabolic health status, obesity, demographic and clinical characteristics and lifestyle factors were compared and analyzed. Items of the health and examination surveys were appropriately selected based on the purpose of the study. The prevalence of major chronic diseases, education, economic activity, and PA were surveyed using questionnaires, and drinking and smoking habits were self-reported. Physical measurements of height, weight, waist circumference (WC), BP, and blood test results were directly measured.

2.2 Clinical examination, sociodemographic and health-related survey

Sociodemographic characteristics, such as age, education level, household income, smoking, alcohol consumption, occupation, and marital status, were investigated using a questionnaire. Physical parameters such as height, weight, body mass index (BMI), and WC were measured.

For clinical examination, BP and blood lipid analysis were measured by professional nurses, and individuals recorded as taking medications related to hypertension or dyslipidemia in the questionnaire were classified as diagnoses. BP was measured three times using a mercury sphygmomanometer, and the average of the second and third measurements was used in the analysis. If the BP was above the standard value, it was re-measured after sufficient relaxation for more than 30 minutes, considering the white coat phenomenon caused by the clinic tension.

Blood was collected after fasting for at least 8 h. Fasting blood glucose, total cholesterol (TC), high-density lipoprotein cholesterol (HDLC), low-density lipoprotein cholesterol (LDLC), fasting glucose (FG), hemoglobin A1c (HbA1c), and triglyceride (TG) levels were measured.

2.3 Physical activities survey

The PA survey was conducted for the study using the widely disseminated WHO IPAQ questionnaire [17] and additional questionnaires on moving place, occupational, and leisure activity PA [18]. The survey method was carried out by self-filling a paper questionnaire using a pen in a 7-day memory recall method. A research assistant was supported if there were difficulties in understanding sentences or low vision. The PA was recorded in terms of days, hours, and minutes by type and was recorded as the total amount of minutes per week (min/week) performed during the week for analysis.

This document analyzed PA I based on the WHO IPAQ, and total amount, vigorous and moderate intensity, walking time, and sedentary time were analyzed. PA II was an additionally conducted questionnaire, which included moving place and occupational and leisure PA. For detailed analysis, it was divided based on vigorous PA $>$75 min/week and moderate PA $>$150 min/week and on the recommended amount of exercise per week from the American College of Sports Medicine [19].

Sedentary time refers to non-physical activity, excluding sleeping time. Examples include sitting at a desk, sitting with a friend, sitting while traveling in a car, bus, or train, reading a book, writing, playing cards, watching television, using a computer or smartphone, using the Internet, and listening to music for one day average time. Seven days were investigated, and the average daily sedentary time was applied.

2.4 Obesity and metabolic health definition

For the obesity group, BMI was applied as $\geq$23.0 kg/m^2. Metabolic healthy status was defined as the absence of metabolic syndrome, and the third report of the National Cholesterol Education Program Adult Treatment Panel (NCEP-ATP III) criteria was applied [20]. Obesity-related criteria such as WC and BMI followed those of the Korean Society for the Study of Obesity [21]. The criteria were as follows: BP $\geq$130/85 mmHg, FG $\geq$100 mg/dL, TG $\geq$150 mg/dL, and HDLC $<$40 mg/dL. The criterion for WC was $\geq$90 cm for men. If $\geq$3 of the 5 items were identified, metabolic syndrome was diagnosed. Additionally, the use of prescribed medications for hypertension, diabetes, and dyslipidemia was included as risk factors.

2.5 Data analysis

For all measured data, the mean and standard deviation or ratio were calculated, and all statistical processing was performed using Statistical Package for the Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA). At first, to identify the factors affecting the clinical characteristics according to the

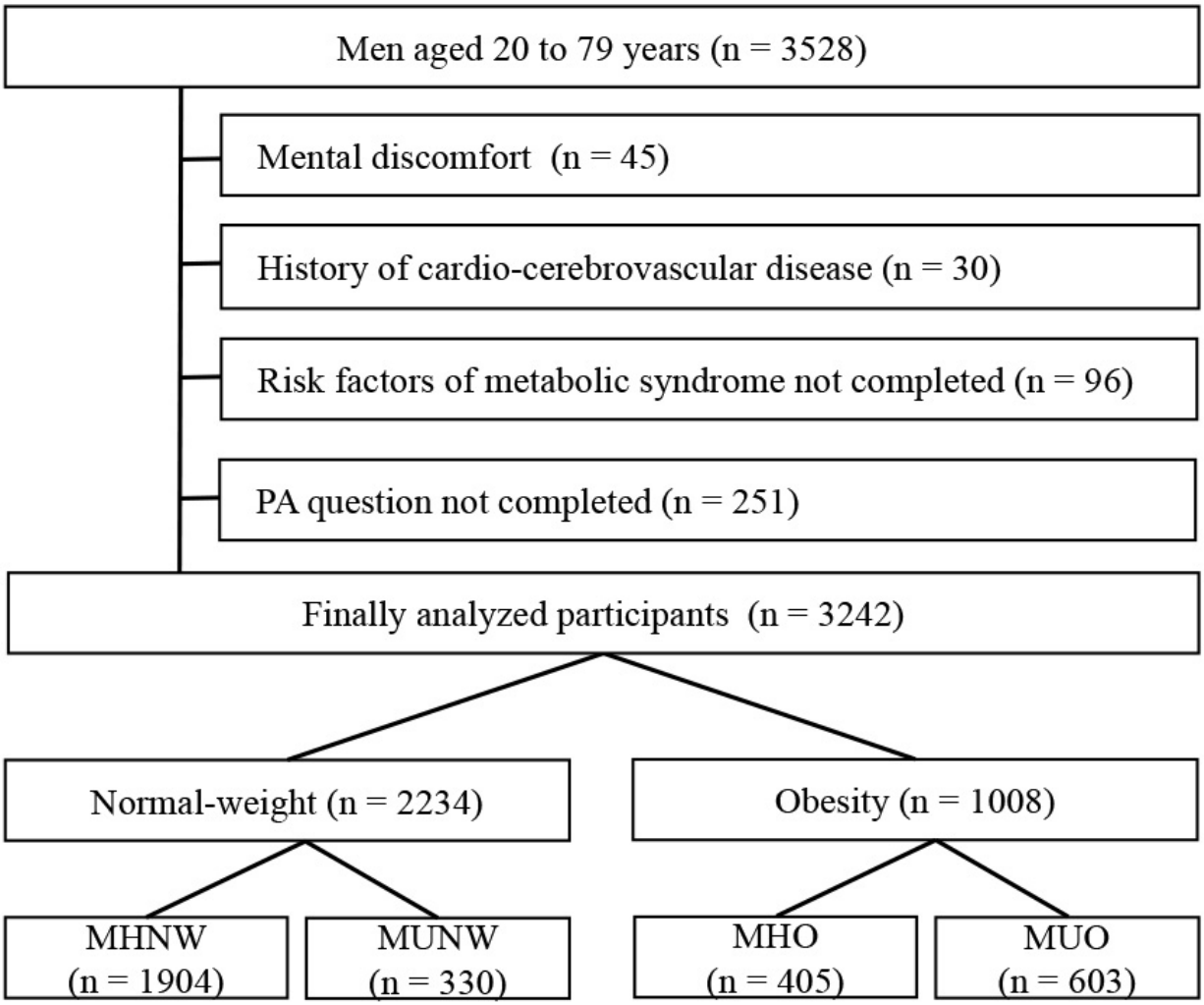

FIGURE 1. Participants' inclusion and exclusion diagram. PA: physical activity; MHNW: Metabolically Healthy Normal Weight; MUNW: metabolically unhealthy normal weight; MHO: metabolically healthy obesity; MUO: metabolically unhealthy obesity.

obesity type and metabolic characteristics of the participants, they were classified as normal weight and obesity. After dividing into 4 groups by obesity phenotype, one-way ANOVA and Bonferroni for *post-hoc* were applied to compare the clinical characteristics according to the participants' obesity types and metabolic characteristics. Categorical variables were recorded in numbers and ratios, and a chi-square test was conducted. Finally, multiple logistic regression analysis was performed to analyze the prevalence of metabolic syndrome according to PA and sedentary time in normal weight and obesity groups. Adjusted variables were selected age, level of education, income, and alcohol drinking as significant variables using stepwise multiple regression analysis. The significance level was set at $p < 0.05$.

3. Results

3.1 Demographic characteristics of participants

Table 1 presents the general sociodemographic characteristics of the participants. Of the participants, 68.9% were of normal weight, and 31.1% were obese. There were significant differences regarding age, education, income, and alcohol drinking between the normal weight and obesity groups; however, there were no significant differences in smoking status, occupation, and marital status. MUNW was 14.8% in the normal weight group, and MHO was 30.3% in the obesity group.

3.2 Physical and clinical characteristics according to obesity phenotype

Physical and clinical characteristics of metabolic health and obesity phenotype are shown in Table 2. All variables showed significant differences between groups ($p < 0.05$). As a result of comparing the MUNW group and the MHO group, the main analysis of this study, the MHO group had higher obesity than the MUNW group, but SBP, diastolic blood pressure (DBP), FG, HbA1c, TG, LDLC, and TC were significantly lower.

In comparison between MHO and MHNW, the same health group, there were significant differences in BMI, WC, DBP, TG, HDLC, and TC, but no significant differences in SBP, FG, HbA1c, and LDLC. Also, compared with MHNW, MUNW, and MHO, MUO had metabolically unhealthy values in all variables except for age and height.

TABLE 1. Sociodemographic characteristics of participants.

Variables	Category	Normal weight (n = 2234; 68.9%)	Obesity (n = 1008; 31.1%)	*p*-value
Age, years	Mean ± SD	48.3 ± 16.1	54.1 ± 18.0	0.024
Age groups, n (%)				
	29–29	447 (20.0%)	99 (9.8%)	0.031
	30–39	451 (20.2%)	128 (12.7%)	
	40–49	331 (14.8%)	154 (15.3%)	
	50–59	351 (15.7%)	196 (19.4%)	
	60–69	360 (16.1%)	227 (22.5%)	
	70–79	295 (13.2%)	205 (20.3%)	
Education levels, n (%)				
	Elementary school	378 (16.9%)	259 (25.7%)	0.005
	Middle school	398 (17.8%)	243 (24.1%)	
	High school	731 (32.7%)	307 (30.5%)	
	College or university	728 (32.6%)	199 (19.7%)	
Income level, n (%)				
	Low	409 (18.3%)	256 (25.4%)	0.014
	Middle	1220 (54.6%)	572 (56.7%)	
	High	605 (27.1%)	180 (17.9%)	
Smoking, n (%)				
	Never smoker	1271 (56.9%)	440 (43.7%)	0.119
	Past smoker	436 (19.5%)	207 (20.5%)	
	Current smoker	527 (23.6%)	361 (35.8%)	
Alcohol drinking, n (%)				
	Non-drinking	804 (36.0%)	258 (25.6%)	0.025
	Current drinking	1430 (64.0%)	750 (74.4%)	
Occupation, n (%)				
	No	784 (35.1%)	398 (39.5%)	0.618
	Yes	1450 (64.9%)	610 (60.5%)	
Marital status, n (%)				
	Yes	1906 (85.3%)	822 (81.5%)	0.781
	No	328 (14.7%)	186 (18.5%)	
Metabolically healthy and obesity phenotype, n (%)				
	MHNW	1904 (85.2%)	–	–
	MUNW	330 (14.8%)	–	
	MHO	–	305 (30.3%)	
	MUO	–	703 (69.7%)	

p-value < 0.05; SD, standard deviation; MHNW, Metabolically Healthy Normal Weight; MUNW, Metabolically Unhealthy Normal Weight; MHO, Metabolically Healthy Obesity; MUO, Metabolically Unhealthy Obesity.

TABLE 2. Physical and clinical characteristics by obesity phenotype.

Variables	MHNW (n = 1904)	MUNW (n = 330)	MHO (n = 405)	MUO (n = 603)	*p*-value
Age, years	48.8 ± 16.5	57.1 ± 12.9 ^{a}	49.8 ± 15.9	56.8 ± 14.9^{ac}	<0.001
Height, cm	170.6 ± 6.1	170.8 ± 6.6	171.5 ± 6.4 ^{ab}	170.2 ± 6.5	0.005
Weight, kg	65.0 ± 6.7	66.1 ± 6.2	77.8 ± 8.1 ^{ab}	80.3 ± 9.1 ^{abc}	<0.001
BMI, kg/m^2	22.3 ± 0.7	22.7 ± 0.6 ^{a}	26.5 ± 2.5 ^{ab}	27.7 ± 2.1 ^{abc}	0.002
WC, cm	85.9 ± 5.4	86.4 ± 5.9 ^{a}	93.7 ± 6.8 ^{ab}	98.9 ± 6.8 ^{abc}	<0.001
SBP, mmHg	117.2 ± 11.4	133.4 ± 15.7 ^{a}	118.2 ± 10.2^{b}	136.1 ± 13.1 ^{abc}	<0.001
DBP, mmHg	72.4 ± 8.2	86.3 ± 12.0 ^{a}	76.0 ± 7.9 ^{ab}	88.8 ± 10.0 ^{abc}	<0.001
FG, mg/dL	96.4 ± 19.0	116.4 ± 33.1^{a}	97.8 ± 15.9 ^{b}	125.0 ± 27.3 ^{abc}	0.030
HbA1c, mmol/L	5.60 ± 0.78	6.13 ± 1.26 ^{a}	5.81 ± 0.91^{b}	6.34 ± 0.89 ^{abc}	<0.001
TG, mg/dL	134.9 ± 98.2	201.8 ± 152.5 ^{a}	169.7 ± 98.0 ^{ab}	236.4 ± 153.4 ^{abc}	<0.001
HDLC, mg/dL	50.8 ± 10.5	45.4 ± 12.1^{a}	47.2 ± 10.7 ^{ab}	40.2 ± 10.7 ^{abc}	0.023
LDLC, mg/dL	109.3 ± 29.7	120.0 ± 31.1^{a}	113.2 ± 31.3^{b}	129.9 ± 37.1^{abc}	0.012
TC, mg/dL	168.2 ± 31.1	178.2 ± 29.4	182.9 ± 38.1 ^{ab}	195.3 ± 31.7 ^{abc}	<0.001

$p < 0.05$; a, vs. MHNW; b, vs. MUNW; c, vs. MHO; The values are shown as the mean ± standard deviation or percent; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; HbA1c, Hemoglobin A1c; TG, triglycerides; HDLC, high-density lipoprotein cholesterol; LDLC, low-density lipoprotein cholesterol; TC, total cholesterol; MHNW, Metabolically Healthy Normal Weight; MUNW, Metabolically Unhealthy Normal Weight; MHO, Metabolically Healthy Obesity; MUO, Metabolically Unhealthy Obesity.

3.3 Prevalence of MUNW for physical activity and sedentary time in the normal weight group

Table 3 shows the odds ratio of MUNW in the normal weight group according to the PA. The group with the low total PA had a 2.0-fold increased risk of becoming MUNW compared to the high total PA in the normal weight group. The odds ratio of MUNW increased 1.8-fold after adjustment in the group who engaged in the low leisure-related PA compared to the high PA. Meanwhile, even if they were of normal weight, those who sat the longest increased the prevalence of MUNW 1.5-fold compared to those who sat the least.

3.4 Prevalence of MHO for physical activity and sedentary time in obesity

MHO is metabolically healthy even if obese, and the higher the odds ratio in Table 4, the more positive it is. It can be observed that the higher the total PA, the higher the 1.7 times the possibility of MHO. Participation in vigorous PA increased the likelihood of becoming MHO, but this was not statistically significant in this result. However, the group doing a lot of vigorous PA, which is highly likely to become MHO, increased 1.5 times, and the group with the low sedentary time increased 1.67 times. In addition, the group with the high leisure PA showed a 1.4-fold increase in the odds ratio of MHO compared to the low leisure PA.

4. Discussion

Individuals in the obesity group are not necessarily metabolically unhealthy, and individuals in the normal weight group are not necessarily metabolically healthy. This study compared obesity phenotypes and metabolic health indices and approached the occurrence of MHO and MUNW using several PAs and sedentary time. This analysis will be the basis for PA to prevent MUNW and to be metabolically healthy for obese people. According to a study by Gómez-Zorita *et al.* [8], the prevalence of MHO varies from 6–75% depending on the definitional criteria. Moreover, in another study, the prevalence of MUNW was 16–26% [22]. This is because several organizations publish diagnostic criteria for metabolic health [13, 23].

One of the main results of this study is that although MHO was obese, some metabolic health indices showed better values than MUNW of normal weight. Even the SBP, FG, HbA1c, and LDLC of MHO were not significantly different from those of MHNW of normal weight. These results support the fact that obesity can be metabolically healthy and that normal weight can be metabolically unhealthy. Conversely, MHO can also be healthier than MUNW. This study did not distinguish between overweight and obesity groups using BMI. However, a previous study showed that HDLC, LDLC, TG, SBP, and DBP within the same metabolically healthy or unhealthy group were not significantly different in the overweight group compared to the normal weight group but were significantly different in the obesity group [24].

In this study, we tested the hypothesis that lifestyle factors such as PA and sedentary time play important roles in determining metabolic health and obesity. The clinical characteristics of MHO in this study were similar to those reported previously. Lifestyle factors, including PA, play important roles in maintaining metabolic health and preventing obesity [25–27]. Conversely, an increased sedentary lifestyle increases the

TABLE 3. Odds ratio of MUNW for physical activity and sedentary time in normal weight.

PA type	Mean ± SD	Crude OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
PA I, total amount of PA, min/week					
High	1245.7 ± 551.3	Reference	–	Reference	–
Middle	412.3 ± 98.1	0.845 (0.744–1.168)	0.351	0.973 (0.767–1.254)	0.241
Low	182.1 ± 45.3	1.256 (0.803–1.847)	0.151	2.050 (1.015–2.950)	0.011
PA I, vigorous PA, >75 min/week					
Yes	254.3 ± 134.5	Reference	–	Reference	–
No	42.3 ± 14.3	1.472 (0.756–2.327)	0.124	1.608 (1.019–2.712)	0.012
PA I, moderate PA, >150 min/week					
Yes	320.1 ± 120.9	Reference	–	Reference	–
No	91.1 ± 36.2	1.847 (0.854–2.541)	0.141	1.502 (0.758–3.210)	0.069
PA I, walking time, min/week					
High	745.2 ± 312.3	Reference	–	Reference	–
Middle	375.6 ± 34.8	0.945 (0.699–1.234)	0.235	0.960 (0.775–1.241)	0.198
Low	178.5 ± 75.2	1.189 (0.701–1.312)	0.456	1.078 (0.699–1.215)	0.310
PA I, sedentary time, min/day					
Low	201.5 ± 74.1	Reference	–	Reference	–
Middle	452.3 ± 85.2	1.089 (0.765–1.130)	0.184	1.061 (0.842–1.321)	0.285
High	751.1 ± 142.3	2.195 (0.771–3.532)	0.198	1.521 (1.011–2.245)	0.015
PA II, moving place and occupational PA, min/week					
High	1010.2 ± 512.4	Reference	–	Reference	–
Middle	412.6 ± 113.6	0.875 (0.689–1.034)	0.348	0.977 (0.778–1.256)	0.215
Low	71.0 ± 35.1	1.019 (0.742–1.850)	0.540	1.080 (0.790–1.978)	0.332
PA II, leisure PA, min/week					
High	524.9 ± 198.4	Reference	–	Reference	–
Middle	222.3 ± 58.2	1.502 (0.974–2.501)	0.169	1.746 (1.121–3.241)	0.012
Low	82.4 ± 31.1	1.780 (1.145–3.180)	0.010	1.861 (1.090–3.501)	0.005

p-value < 0.05; SD, standard deviation; CI, confidence interval; MUNW, metabolically unhealthy normal weight; OR, odds ratio; PA, physical activity; Adjusted variables: age, level of education, income, and alcohol drinking.

risk [28]. A sedentary lifestyle refers to PA in which energy consumption is less than 1.5 metabolic equivalents; an increase in sedentary time independently increases the risk of diabetes and cardiovascular events, regardless of PA [29]. Although there are limited studies on the relationship between sedentary time and MHO, it has been reported that cessation of PA increases the likelihood of transitioning to MUO from MHO. This supports the relationship between increased sedentary time and MUO [5]. A positive mechanism for high PA and low sedentary in obese individuals is fatty acid oxidation. In physiological mechanics, lifestyle such as PA might modulate whole-body energy metabolism, as the evidence suggests that concurrent PA increases fatty acid oxidation during high-calorie intake. Specifically, MHO individuals have a higher fat utilization rate than MUO individuals. In the same study, results reported that insulin sensitivity is positively associated with the ability to extract energy from fat [30].

In this study, low PA had a low probability of MHO, and high PA could lower MUNW. These studies also appear in previous studies. Messier *et al*. [31] reported that increased PA increased the rate of MHO in obese individuals, and Hinnouho *et al*. [32] reported that increased PA decreased insulin resistance, a major defining factor of MHO and MUO. However, some studies have not shown consistent results. Some studies did not identify differences in PA as an MHO influencing factor. Hankinson *et al*. [33] stated that there was no significant difference between dietary factors and PA in MHO and MUO. There was no difference in PA between MHO and MUO in African-American women in South Africa [34]. Additionally, Phillips *et al*. [35] found that MHO and MUO did not differ in the level of PA intensity and the percentage of total daily PA that met the guidelines. In addition, although the study only asked whether PA participated, a study also showed that PA did not necessarily show a clear difference from the phenotype, only that obesity had a higher PA than normal weight [36].

In our logistic regression analysis, the adjusted odds ratio of MHO in the vigorous, walking, moving place, and occupational PA of the obesity group was not significant. Furthermore, sedentary time was an influencing factor in either MHO or MUNW. These results were similar to those of previous

TABLE 4. Odds ratio of MHO for physical activity and sedentary time in obesity.

PA type	Mean ± SD	Crude OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
PA I, total amount of PA, min/week					
Low	102.1 ± 40.7	Reference	–	Reference	–
Middle	322.3 ± 125.3	1.356 (0.898–1.489)	0.298	1.023 (0.756–1.278)	0.241
High	1024.5 ± 475.3	1.958 (1.101–3.977)	0.031	1.741 (1.078–3.670)	0.016
PA I, vigorous PA, >75 min/week					
No	39.8 ± 19.0	Reference	–	Reference	–
Yes	201.5 ± 214.2	1.701 (0.979–3.521)	0.135	1.612 (0.845–3.205)	0.303
PA I, moderate PA, >150 min/week					
No	81.9 ± 60.2	Reference	–	Reference	–
Yes	314.7 ± 123.2	1.316 (0.801–2.019)	0.488	1.512 (1.059–3.183)	0.005
PA I, walking time, min/day					
Low	132.5 ± 24.4	Reference	–	Reference	–
Middle	310.5 ± 22.3	1.021 (0.815–1.310)	0.410	1.156 (0.846–1.385)	0.209
High	645.5 ± 451.2	1.218 (0.879–1.412)	0.341	1.260 (0.890–1.421)	0.187
PA I, sedentary time, min/day					
High	810.2 ± 148.3	Reference	–	Reference	–
Middle	456.1 ± 60.1	1.286 (0.756–2.405)	0.519	1.177 (0.681–1.138)	0.112
Low	234.4 ± 58.4	2.504 (1.690–4.139)	0.002	1.670 (1.125–2.850)	0.009
PA II, moving place and occupational PA, min/week					
Low	73.2 ± 60.2	Reference	–	Reference	–
Middle	245.7 ± 102.3	1.129 (0.869–1.439)	0.258	0.991 (0.757–1.323)	0.432
High	859.0 ± 401.2	1.311 (0.852–1.689)	0.301	1.172 (0.878–1.533)	0.264
PA II, leisure PA, min/week					
Low	79.4 ± 25.5	Reference	–	Reference	–
Middle	204.5 ± 40.1	1.130 (0.670–1.601)	0.621	1.002 (0.878–1.314)	0.284
High	521.8 ± 224.4	1.356 (0.988–2.140)	0.410	1.412 (1.191–2.394)	0.018

p-value < 0.05; SD, standard deviation; CI, confidence interval; MHO, metabolically healthy obesity; OR, odds ratio; PA, physical activity; Adjusted variables: age, level of education, income, and alcohol drinking.

studies [28, 29]. A study by Valérie Julian showed similar results. The sedentary time of adolescents with obesity was a stronger and more independent impact on metabolic health than moderate to vigorous PA [37]. However, the study of sedentary time has some difficulties. Since the study of sedentary time generally followed the memory recall questionnaire method, there may be limitations in accurate measurement when sedentary for a long time. Therefore, the method for measuring sedentary time should be considered.

Although this study has limitations in clarifying the effect of PA on MUNW and MHO, PA was subdivided into several types. An obese adult can be metabolically healthy; conversely, a normal weight is possible but may not be metabolically healthy. Among various causes, PA or a long sedentary life affects these results. Therefore, clinically practical experts should emphasize a normal weight for adults without cardiovascular disease and make patients aware of the need for a low sedentary lifestyle and high PA because clinical experts do not consider MHO stable and positive. This is because obesity and metabolic health can change from time to time, depending on management intensity. According to a previous study, only 57.2% maintained MHO, and 42.8% changed to MUO in a reinvestigation two years later [5]. Similarly, Gilardini *et al.* [38] found that 44% and 62% of MHOs were unhealthy after 6 and 12 years, respectively.

Our present study has several limitations. Because of the wide age range, PA may vary between older and younger adults. Moreover, since it is a cross-sectional study, causality cannot be confirmed, and further studies will require longitudinal studies to explain the causal relationship. Although low PA can cause metabolic syndrome, conversely, people with metabolic syndrome or chronic diseases may have low levels of physical strength and PA due to musculoskeletal pain [39, 40]. This study did not include dietary surveys or surveys of body composition, such as muscle mass. In order to prevent or improve metabolic syndrome in the future, it is necessary to classify more diverse age groups and conduct prospective or case-control studies. To evaluate the effects of PA and a sedentary lifestyle on MHO and MUNW phenotypes, objective and sensory metrics such as accelerometers and cardiorespira-

tory fitness are required. Long-term follow-up studies will be needed in the future.

5. Conclusions

Even in obese people, MHO showed better BP, FG, TG, HDLC, and TC values than MUNW of normal weight. Moreover, SBP, FG, and LDLC were not different from MHNW. The probability of being MUNW in the normal weight group increased as the vigorous and leisure PA was lower and the sedentary time was longer. Meanwhile, the probability of being MHO in the obesity group increased as the moderate and leisure PA was higher and the sedentary time was shorter. Low total PA increased MUNW, and high total PA increased MHO.

AVAILABILITY OF DATA AND MATERIALS

The data are not publicly available due to privacy or ethical reasons.

AUTHOR CONTRIBUTIONS

These should be presented as follows: YK and JL—Conceptualization; GZ and YC—methodology; YK and YC—formal analysis; JL—investigation; GZ and JL—original draft writing; YK and YC—review and editing; YC and JL—supervision. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All participants gave their written consent for examination and publication for the purpose of the study. This study was approved by the Research Ethics Committee of the Gangneung-Wonju National University (GWNUIRB-R2020-16).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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