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Changes in physical activity and energy intake according to abdominal obesity in Korean adult men before and after COVID-19: Data from 2019 and 2020 Korea National Health and Nutrition Examination Survey (KNHANES)

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[Purpose] This study aimed to investigate changes in physical activity and energy intake according to abdominal obesity in Korean adult men before and after COVID-19.

[Methods] Using data from the 2019 and 2020 KNHANES, the physical activity level measured by the Global Physical Activity Questionnaire (GPAQ) the physical activity level by GPAQ, number of days of walking and strength training, aerobic exercise, and total energy, protein, fat, carbohydrate, dietary fiber, and sugar intake for a total of 2,799 participants were analyzed.

[Results] There were no changes in energy intake during the pandemic. The number of days of weekly walking was higher (2019, p = 0.006; 2020, p = 0.012) and strength training was significantly higher (2019, p < 0.0001; 2020 p < 0.0001) in the non-abdominal obesity group than in the abdominal obesity group before and after COVID-19. Strength training at least once a week suppressed abdominal obesity (0.628 times in 2019, p < 0.0001; 0.605 times in 2020, p < 0.0001). In addition, even when the total energy intake and age were adjusted for, strength training influenced the suppression of abdominal obesity (0.634 times in 2019, p < 0.0001; 0.614 times in 2020, p < 0.0001).

[Conclusion] Even with the change in the physical activity level, such as walking and aerobic exercise, due to the influence of social distancing measures, strength training influenced the suppression of abdominal obesity, regardless of the COVID-19 pandemic.

[Keywords] COVID-19 pandemic, social distancing measures, abdominal obesity, physical activity, energy intake, strength training

INTRODUCTION

Obesity is a public health risk factor in Korea, even before the COVID-19 pandemic. According to the Korean body mass index (BMI) classification, the prevalence of obesity among adults in 2019 was 34.4%, the pre-obesity stage was 22.5%, and more than 50% of adults were subject to obesity management[1]. Regarding the obesity rate in Korea, it is worth noting that the obesity rate in men has steadily increased over the past 20 years. The obesity rate in men, which was 25.1% in 1998, increased to 41.4% in 2019, which was severe compared to the obesity rate in women, which remained at a similar level (an increase from 26.2% to 27.3%) during the same period[2]. In addition, the increase in the obesity rate after the pandemic was even greater, suggesting that active management is required (prevalence of obesity: 48% for men in 2020 and 41.8% in 2019)[3]. Clinical studies on obesity and COVID-19 have indicated that obesity and obesity-related underlying diseases, such as hypertension, diabetes, dyslipidemia, and heart disease, are major causes of increased infection, severe morbidity, and mortality[4-7].

To control the spread of COVID-19, Korea had implemented social distancing measures from March 2020 to April 2022. Although the degree of social distancing had been repeatedly reinforced and mitigated while interacting with the spread of COVID-19, the rate of working from home increased. Student classes were replaced by online classes, and operations of parks, gyms, shops, restaurants, and non-essential businesses or services were shortened or suspended[8]. These were effective public health strategies that minimized contact between individuals or groups from an epidemiological point of view[9,10]. However, the prolonged quarantine situation led to daily changes, such as a reduction in outside activities and an increase in the time spent at home, which affected weight-related health behaviors, such as physical activity (PA) and energy intake[11-13].

Most studies on changes in PA and diet during the COVID-19 pandemic reported a decrease in PA and an increase in sedentary lifestyles[14-17], except for some studies on children and adolescents[18,19]. Some diet-related studies have reported positive changes, such as increased consumption of healthy food and home-cooked meals and reduced consumption of alcohol[14,20-22]. However, most studies have reported negative changes, such as an increase in the amount of food consumed, night snacking, alcohol consumption, and energy intake[23-27].

Although the results are inconsistent, changes in PA, diet, and body weight are key to life changes due to the COVID-19 pandemic. In particular, from the viewpoint of obesity, even small changes in PA and energy intake are sufficient to cause weight gain by breaking the energy balance through a cumulative effect over time[28]. PA and energy intake are also important for modifiable health behaviors.

Therefore, this study aimed to confirm changes in PA and energy intake according to the presence of abdominal obesity in Korean men before and after the COVID-19 pandemic using data from the Korea National Health and Nutrition Examination Survey (KNHANES). Furthermore, the results of this study could be used as basic data to recognize the importance of PA and energy intake during pandemics, in which the spread of infectious diseases continues.

METHODS

Sample and design

This study used data from the 2019 and 2020 KNHANES, which was conducted by the Korean Centers for Disease Control and Prevention (KCDC), to analyze changes in PA and energy intake according to abdominal obesity in adult men before and after the COVID-19 pandemic. This survey was approved by the Institutional Review Board (reference numbers 2018-01-03-C-A and 2018-01-03-2C-A) of the KCDC. All participants who took part in the survey signed an informed consent form.

Adult men between the ages of 19 and 64 years were excluded from the study if any of the following criteria were met: 1) diagnosis of serious cardiovascular disease or various cancers; 2) missing values in the main research variables: anthropometric, health examination, and nutrition survey; and 3) daily energy intake less than 500 kcal or more than 5,000 kcal. Finally, 2,799 study participants were included (Figure 1).

Measures

The KNHANES inspection, examination, and nutrition survey data were used in the analysis. Using age, height, and body weight as basic variables, body mass index (BMI), waist circumference (WC), blood pressure, fasting blood sugar, triglyceride (TG), and high-density lipoprotein cholesterol (HDL-C) levels, which are risk factors for metabolic syndrome and can be used as health indicators in adult men, were analyzed. PA variables were evaluated using the Global Physical Activity Questionnaire (GPAQ), and PA was expressed as metabolic equivalents (MET) minutes per week. In addition, questionnaire data on walking and strength exercise per week were analyzed. The total energy intake was analyzed using the 24 h recall method, and the amount of calories, nutrients (carbohydrates, proteins, and fats), fiber, and simple sugar intake were analyzed. Table 1 presents the characteristics of the participants in 2019 and 2020.

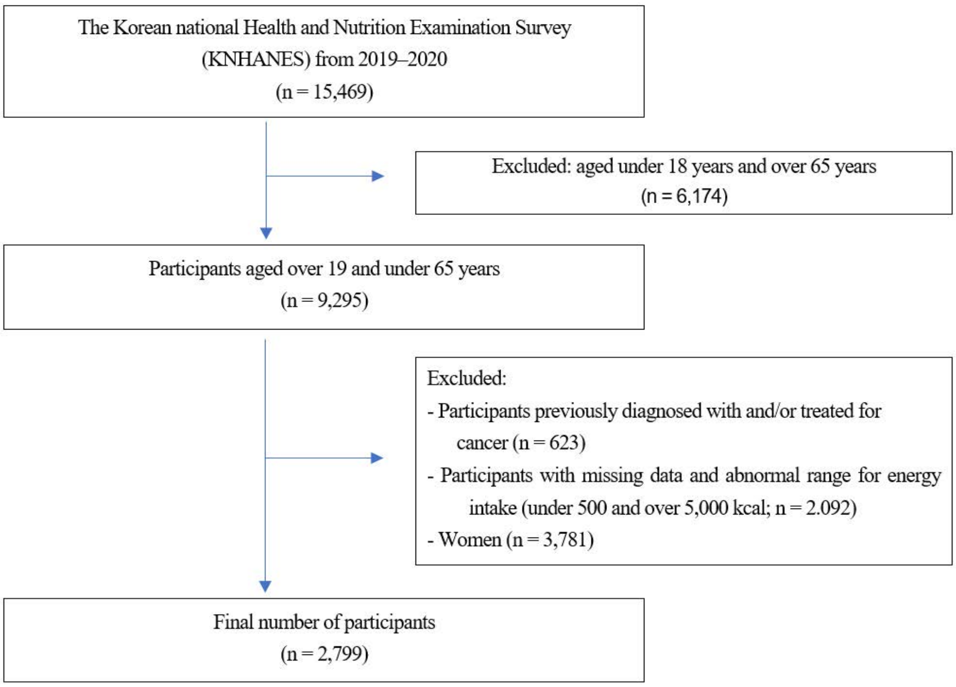

Figure 1. Flow diagram of the selection of study participants.

Table 1. Participant characteristics of before and after COVID-19 pandemic.

Variables	Before and After COVID-19		
	2019 (n=1525)	2020 (n=1274)	p-value
Age (years)	43.77(0.33)	43.62(0.37)	0.751
Anthropometries			
Height (cm)	172.67(0.16)	172.90(0.18)	0.350
Body weight (kg)	73.85(0.31)	75.36(0.36)	0.001**
BMI (kg/m²)	24.72(0.09)	25.16(0.10)	0.001**
Metabolic syndrome risk factors			
WC (cm)	87.33(0.24)	88.75(0.28)	<.0001***
Fasting glucose (mg/dL)	101.57(0.59)	102.81(0.70)	0.175
TG (mg/dL)	157.69(3.29)	163.39(3.78)	0.254
HDL-C (mg/dL)	49.38(0.30)	47.48(0.31)	<.0001***
SBP (mmHg)	118.70(0.34)	119.07(0.38)	0.458
DBP (mmHg)	78.73(0.24)	79.66(0.27)	0.011*
Physical activities			
Walking (days/week)	3.94(0.07)	3.71(0.07)	0.024*
Strength training (days/week)	1.21(0.05)	1.21(0.05)	0.919
Total Physical activity (MET)	1114.00(41.93)	1088.07(43.80)	0.670
Intakes of Total energy and nutrients			
Total energy intake (kcal/day)	2292.45(21.42)	2273.03(23.28)	0.539
Protein intake (g/day)	85.65(1.01)	86.90(1.12)	0.410
Fat intake (g/day)	56.79(0.94)	59.09(1.03)	0.100
Carbohydrate intake (g/day)	316.50(2.92)	308.51(3.20)	0.065
Dietary fiber intake (g/day)	25.74(0.32)	26.51(0.37)	0.115
Simple sugar intake (g/day)	65.51(1.11)	61.77(1.14)	0.020*

Values are expressed as mean ± standard error. BMI, body mass index; WC, waist circumstance; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure. *p<.05, **p<.01, ***p<.001.

Abdominal obesity

Asians have a higher body fat percentage, abdominal obesity rate, and intracellular lipid levels than Caucasians, even with the same BMI[29]. In addition, it has been reported that abdominal obesity, an indirect indicator of visceral fat, increases insulin resistance and related metabolic diseases as well as the secretion of inflammatory cytokines. Inflammation is associated with a cytokine storm in patients with COVID-19[30]. Therefore, considering these racial differences and metabolic risks, WC was used as an indicator of obesity in this study. WC was measured using a tape, measured above the navel, and the cut-off point of WC for abdominal obesity in Koreans was 90 cm in men[31].

Physical activity

The GPAQ was used to investigate the amount of moderate- and vigorous-intensity activity in four different behavioral domains: PA at work, place movement, recreational activities, and sedentary behavior. The GPAQ data were analyzed using the World Health Organization (WHO) GPAQ analysis guidelines[32]. The MET-min/week score was calculated using the GPAQ, including the frequency (day/week) and time (min/day) of PA for each domain as follows:

- Vigorous intensity activity: occupational (MET) = 8.0 × vigorous-intensity PA (day/week) × 1-day vigorous-intensity PA (min/day)
- Moderate-intensity activity: occupational (MET) = 4.0 × moderate-intensity PA (day/week) × 1-day moderate-intensity PA (min/day)
- Vigorous intensity activity: recreational (MET) = 8.0 × vigorous-intensity PA (day/week) × 1-day vigorous-intensity PA (min/day)
- Moderate-intensity activity: recreational (MET) = 4.0 × moderate-intensity PA (day/week) × 1-day moderate-intensity PA (min/day)
- Place movement (MET) = 4.0 × place movement PA (day/week) × 1-day place movement PA
- Total physical activity (MET) = vigorous intensity activity: occupational + moderate intensity activity: occupational + vigorous intensity activity: recreational + moderate intensity activity: recreational + place movement

In addition, among the PA questionnaires of the KNHANES, the number of days of walking and strength training per week and aerobic exercise were classified and analyzed as follows:

- Walking: In the previous week, the total number of days walked for more than 30 min/day (classified as practice for 0 to 3 days per week and 4 or more days per week).

- Strength training: Number of days of strength training, such as push-ups, sit-ups, use of dumbbells, and weights, in the past week (classified as practice for 0, 1, or more days per week).
- Aerobic exercise: 150 min or more of moderate-intensity PA, 75 min or more of high-intensity PA per week, or mixed moderate- and high-intensity PA (classified according to whether the time equivalent to each activity was practiced).

Energy intake

The total energy and energy nutrient intakes were surveyed using the 24 h recall method. Nutrition survey data, meal type, and serving size were collected in chronological order the day before the survey. The analyses included the following variables: total energy, protein, fat, carbohydrate, dietary fiber, and simple sugar intake.

Statistical analysis

All statistical analyses were performed using the SPSS software version 26.0 (version 26.0; IBM, Armonk, NY, USA). Categorical data were presented as counts (n) and percentages (%), and continuous data were analyzed using mean and standard error (SE). The level of significance was set at $p < 0.05$. To compare changes in health behaviors related to abdominal obesity in adult Korean men due to the COVID-19 pandemic, this study calculated the descriptive statistics of the indicators measured before and after the pandemic. Differences in general characteristics, anthropometrics, PA, and nutrient intake according to abdominal obesity were compared using an independent t-test. Categorical data of the variables used in this study were analyzed using the chi-squared test. To determine the effect of the PA type on abdominal obesity in adult men, simple logistic regression analysis was performed. In this study, data from the KNHANES were used as raw data, and all analyses were interpreted as a cross-sectional study.

RESULTS

General characteristics of participants before and after the COVID-19 pandemic

The general characteristics of the participants are presented in Table 1. Comparison of the results before (2019) and after (2020) the pandemic shows that there are no differences in age, height, fasting glucose, TG, systolic blood pressure (SBP), the number of days of strength training per week, total PA (MET), and total energy, protein, fat, carbohydrate, and dietary fiber intake. However, body weight, BMI, WC, and diastolic blood pressure (DBP) increased for one year after COVID-19, whereas HDL-C, walking days per week, and simple sugar intake decreased. The changes in each variable were as follows (numbers in parentheses are in the order of the 2019 and 2020 values): body weight (73.85 kg, 75.36 kg, $p = 0.001$), BMI (24.72 kg/m², 25.16 kg/m², $p = 0.001$), WC (87.33 cm, 88.75 cm, $p < 0.0001$), HDL-C (49.38 mg/dL, 47.48 mg/dL, $p < 0.0001$), DBP (78.73 mmHg, 79.66 mmHg, $p = 0.011$), walking days per week (3.94 days, 3.71 days, $p = 0.024$), and simple sugar intake (65.51 g/day, 61.77 g, $p = 0.020$).

Differences in general characteristics, energy intake, and PA among participants according to the presence or absence of abdominal obesity before and after the COVID-19 pandemic

Based on the presence or absence of abdominal obesity, the general characteristics of the participants and the differences in energy intake and PA were analyzed. In 2019 and 2020, age, height, body weight, BMI, WC, fasting glucose, TG, SBP, and DBP were higher and HDL-C was lower in the abdominal obesity group (Table 2). There were no differences in household income or educational level.

Table 3 shows the differences in the total energy and energy nutrient intake according to the presence or absence of abdominal obesity. There are no differences in total energy, protein, fat, carbohydrate, and dietary fiber intake between 2019 and 2020 according to the presence of abdominal obesity. Regarding dietary variables, simple sugar intake is lower in the abdominal obesity group (62.62 g) than in the non-abdominal obesity group (67.17 g) in 2019 ($p = 0.049$); however, there is no difference in 2020.

As shown in Table 4, there are no statistically significant differences in total PA (MET), occupational vigorous-intensity PA, or place movement PA according to the presence or absence of abdominal obesity before and after the COVID-19 pandemic. The amount of recreational moderate-intensity PA in 2019 was higher in the normal group than in the abdominal obesity group (257.64 MET in the non-abdominal obesity, 194.13 MET in the abdominal obesity group, $p = 0.024$), but there was no difference in 2020. However, recreational vigorous-intensity PA did not differ in the amount of activity according to abdominal obesity in 2019. Nevertheless, in 2020, the amount of recreational vigorous-intensity PA was significantly higher in the non-abdominal obesity group than in the abdominal obesity group (264.48 MET in the non-abdominal obesity group, 162.02 MET in the abdominal obesity group, $p = 0.005$). The occupational moderate-intensity PA was higher in the abdominal obesity group in both 2019 and 2020 than in the non-abdominal obesity group (in 2019: 111.48 MET in the non-abdominal obesity group, 194.73 MET in the abdominal obesity group, $p = 0.024$; in 2020: 126.59 MET in the non-abdominal obesity group, 211.28 MET in the abdominal obesity group, $p = 0.046$). In 2019, the number of walking days per week was 4.08 days in the non-abdominal obesity group and 3.69 days in the abdominal obesity group ($p = 0.006$). In 2020, the number of walking days per week was 3.97 days in the non-abdominal obesity group and 3.50 days in the abdominal obesity group ($p = 0.012$). Moreover, in 2019, the number of days of strength training was1.35 days in the non-abdominal obesity group and 0.98 days in the abdominal obesity group ($p < 0.0001$), while in 2020 the number of days of strength training was 1.43 days in the non-abdominal obesity group and 0.92 days in the abdominal obesity group ($p < 0.0001$).

Table 2. Differences in participant characteristics according to the presence of abdominal obesity before and after COVID-19 pandemic.

Variables	Before and After COVID-19					
	2019 (n=1525)			2020 (n=1274)		
	non-ab-obesity (n=967)	ab-obesity (n=558)	p-value	non-ab-obesity (n=719)	ab-obesity (n=555)	p-value
Age (years)	42.60(0.42)[a)]	45.77(0.50)	<.0001***	42.69(0.51)	44.82(0.52)	0.003**
Household Income						
Low	89(9.1)[b)]	37(6.5)	0.128	69((9.6)	49(8.8)	0.717
Lower intermediate	209(21.6)	139(24.8)		141(19.5)	110(19.9)	
Higher intermediate	284(29.4)	174(31.3)		235(32.6)	169(30.3)	
High	385(39.9)	208(37.4)		274(38.2)	227(41.0)	
Education						
< Middle school	94(9.7)	54(9.6)	0.383	67(9.3)	54(9.8)	0.255
≥ High School	390(40.3)	202(36.2)		309(43.0)	209(37.7)	
≥ College	483(49.9)	302(54.1)		343(47.7)	292(52.6)	
Height (cm)	172.05(0.20)	173.77(0.26)	<.0001***	172.01(0.24)	174.06(0.27)	<.0001***
Body weight (kg)	67.90(0.25)	84.20(0.45)	<.0001***	67.92(0.30)	85.00(0.49)	<.0001***
BMI (kg/m²)	22.92(0.07)	27.85(0.12)	<.0001***	22.94(0.08)	28.03(0.14)	<.0001***
WC (cm)	81.80(0.18)	96.62(0.26)	<.0001***	82.12(0.22)	97.34(0.30)	<.0001***
Fasting glucose (mg/dL)	98.36(0.69)	107.07(1.06)	<.0001***	99.09(0.77)	107.61(1.23)	<.0001***
TG (mg/dL)	137.93(3.82)	192.03(5.84)	<.0001***	140.90(4.57)	192.54(6.19)	<.0001***
HDL-C (mg/dL)	51.40(0.38)	45.88(0.46)	<.0001***	49.86(0.43)	44.39(0.40)	<.0001***
SBP (mmHg)	117.05(0.43)	121.56(0.54)	<.0001***	115.86(0.50)	123.37(0.53)	<.0001***
DBP (mmHg)	77.28(0.30)	81.24(0.40)	<.0001***	77.05(0.34)	83.05(0.39)	<.0001***

a) Values are expressed as mean ± standard error. b) Values are expressed as frequency (percentage between non-ab-obesity and ab-obesity). BMI, body mass index; WC, waist circumstance; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure. *p<.05, **p<.01, ***p<.001.

Table 3. Differences in total Energy and Energy nutrients intake according to the presence of abdominal obesity before and after COVID-19 pandemic.

Variables	Before and After COVID-19					
	2019 (n=1525)			2020 (n=1274)		
	non-ab-obesity (n=967)	Ab-obesity (n=558)	p-value	non-ab-obesity (n=719)	ab-obesity (n=555)	p-value
Total energy Intake (kcal/day)	2312.00(26.59)	2258.86(36.15)	0.233	2250.73(29.68)	2301.93(36.93)	0.280
Protein intake (g/day)	86.11(1.27)	84.92(1.67)	0.570	86.28(1.49)	87.69(1.70)	0.532
Fat intake (g/day)	57.87(1.23)	54.98(1.46)	0.140	58.99(1.35)	59.22(1.60)	0.911
Carbohydrate Intake (g/day)	318.43(3.53)	313.19(5.11)	0.399	307.06(4.25)	310.38(4.87)	0.607
Dietary fiber Intake (g/day)	25.81(0.40)	25.63(0.55)	0.785	26.15(0.51)	26.97(0.54)	0.271
Simple sugar Intake (g/day)	67.17(1.38)	62.62(1.87)	0.049*	61.76(1.45)	61.77(1.84)	0.998

Values are expressed as mean ± standard error. *p<.05.

By dividing the number of walking days into less than three days per week or more than four days per week, 60.9% of the participants in the non-abdominal obesity group and 39.1% in the abdominal obesity group in 2019 and 54.4% of the participants in the non-abdominal obesity group and 45.6% in the abdominal obesity group in 2020 walked for less than three days. In addition, 65.5% of the participants in the non-abdominal obesity group and 34.5% in the abdominal obesity group in 2019 and 58.5% of the participants in the non-abdominal obesity group and 41.5% in the abdominal obesity group in 2020 walked for more than four days per week. However, there was no statistically significant difference between the two groups in terms of the number of days walked per week. In 2019, before the COVID-19 pandemic, 40.9% of the participants in the abdominal obesity group did not do muscle strength training, and 29.3% trained for more than one day per week (p < 0.0001). In 2020, in the early stage of the COVID-19 pandemic, 48.2% of the participants in the abdominal obesity group did not train for muscle strength, while 35.7% trained for more than one day per week (p < 0.0001). There was a significant relationship between aerobic exercise and the presence or

Table 4. Differences in physical activity levels according to the presence of abdominal obesity before and after COVID-19 pandemic.

Variables	Before and After COVID-19					
	2019 (n=1525)			2020 (n=1274)		
	non-ab-obesity (n=967)	ab-obesity (n=558)	p-value	non-ab-obesity (n=719)	ab-obesity (n=555)	p-value
Total Physical Activity (MET)	1131.36(48.61)[a)]	1084.84(77.82)	0.593	1113.44(56.87)	1055.21(68.43)	0.510
Occupational vigorous (MET)	67.34(17.69)	110.47(30.95)	0.227	56.41(21.79)	40.94(20.70)	0.602
Occupational Moderate (MET)	111.48(16.90)	194.73(32.83)	0.024*	126.59(21.79)	211.28(36.25)	0.046*
Recreational Vigorous (MET)	249.00(22.44)	202.08(31.94)	0.220	264.48(27.88)	162.02(22.95)	0.005**
Recreational Moderate (MET)	257.64(16.10)	194.13(20.17)	0.014*	256.36(18.30)	228.25(23.22)	0.335
Place movement (MET)	445.90(23.33)	383.43(31.11)	0.107	409.60(25.96)	412.72(31.57)	0.939
Walking	4.08(0.08)	3.69(0.11)	0.006**	3.87(0.10)	3.50(0.07)	0.012*
≤ 3days/week	421(60.9)[b)]	270(39.1)	0.067	346(54.4)	290(45.6)	0.144
≥ 4days/week	546(65.5)	288(34.5)		373(58.5)	265(41.5)	
Strength training	1.35(0.06)	0.98(0.07)	<.0001***	1.43(0.07)	0.92(0.07)	<.0001***
0day/week	565(59.1)	391(40.9)	<.001***	413(51.8)	385(48.2)	<.001***
≥ 1day/week	402(70.7)	167(29.3)		306(64.3)	170(35.7)	
Aerobic exercise do not	442(45.7)	293(52.5)	0.010*	361(50.2)	300(54.1)	0.173
Aerobic exercise do	525(54.3)	265(47.5)		358(49.8)	255(45.9)	

a) Values are expressed as mean ± standard error. b) Values are expressed as frequency (percentage between non-ab-obesity and ab-obesity). *p<.05, **p<.01, ***p<.001.

Table 5. Odds ratio (95% CI) for abdominal obesity and type of physical activity according to number of days of activity per week.

Variables	Number of Days of PA		Before and After COVID-19			
			2019		2020	
Walking	≤3 days/week		1.0		1.0	
	≥ 4days/week	model 1	0.959(0.758-1.214)	0.729	0.927(0.728-1.181)	0.540
		model 2	1.008(0.794-1.279)	0.949	0.960(0.752-1.225)	0.742
Strength training	0 day/week		1.0		1.0	
	≥ 1day/week	model 1	0.628(0.499-0.789)	<.0001***	0.605(0.474-0.771)	<.0001***
		model 2	0.634(0.504-0.798)	<.0001***	0.614(0.481-0.785)	<.0001***
Practice of aerobic exercise	do not		1.0		1.0	
	do	model 1	0.859(0.678-1.089)	0.210	0.605(0.474-0.771)	0.989
		model 2	0.888(0.700-1.128)	0.331	1.010(0.788-1.293)	0.939

Data presented as odds ratios (95% confidence intervals [CIs]). Model 1: unadjusted. Model 2: adjustment for energy intake and age. ***p<.001.

absence of abdominal obesity in 2019 (p = 0.010); however, there was no significant difference in 2020.

The association between abdominal obesity and PA before and after the COVID-19 pandemic

A logistic regression analysis was performed to evaluate the association between abdominal obesity and PA (Table 5). The results showed that the number of walking days per week and aerobic exercise were not associated with abdominal obesity before and after the COVID-19 pandemic.

Only the number of strength-training days per week had the strongest association with abdominal obesity. If muscle strength training was performed for more than one day per week, abdominal obesity was suppressed 0.628 times in 2019 (p < 0.0001) and 0.605 times in 2020 (p < 0.0001). Abdominal obesity can be affected by age and total energy intake; therefore, the results of Model 2 were analyzed by adjusting for age and total energy intake. Even after adjusting for age and total energy intake, strength training for more than one day per week suppressed abdominal obesity by 0.634 times in 2019 (p < 0.0001) and 0.614 times in 2020 (p < 0.0001).

DISCUSSION

Abdominal obesity is a public health problem even before the COVID-19 pandemic because of its high association with metabolic disease morbidity and mortality and is a major cause of increased risk of COVID-19 infection and associated severe morbidity and mortality. Although social distancing measures are necessary to control the spread of the COVID-19 pandemic, they can also have unintentional negative effects on PA and energy intake, which may worsen the obesity epidemic and its related comorbidities in Korea. Considering the results of previous studies indicating that overweight and obese individuals showed more weight gain during the pandemic than individuals with normal weight[33-35], it is important to compare the differences in PA and energy intake according to the presence or absence of obesity before and after the pandemic. Therefore, this study aimed to identify changes in PA and energy intake as modifiable behavioral risk factors for weight gain according to the presence or absence of abdominal obesity during the pandemic and investigate the association between these factors and abdominal obesity using data from KNHANES 2019 and 2020.

Comparing the general characteristics of participants in 2019 and 2020 before and after the COVID-19 pandemic, body weight, BMI, WC, and DBP increased and HDL-C and the number of days walked per week decreased. However, there were no significant changes in the health indicators, PA, or energy intake during this time. The reason for this, according to a report by the KCDC, could be the factors not included in this study. The report by the KCDC examining weight-related health behaviors indicated that the high-risk drinking rate was highest in middle age, the inactivity rate of aerobic PA was highest in old age, and dietary risk factors were highest in the younger group (the rate of skipping breakfast, eating out more than once a day, and excessive energy intake)[1].

WC is an indirect indicator of visceral fat content. In men, visceral fat accumulation is often the cause of abdominal obesity, unlike in women with subcutaneous fat-type abdominal obesity[36,37]. In addition, visceral fat is known to not only increase metabolic disease but also increase the fatal risk of cytokine storms in COVID-19 patients[30]; thus, more active improvement is required. Therefore, general characteristics were analyzed according to the presence or absence of abdominal obesity. In 2019 and 2020, age, height, body weight, BMI, WC, fasting glucose, TG, SBP, and DBP were higher in the abdominal obesity group and HDL-C was lower in the non-abdominal obesity group. Thus, health-related indicators in individuals with abdominal obesity were worse than those without abdominal obesity.

Comparing the total energy and energy nutrient intakes according to the presence or absence of abdominal obesity, there was no difference between the two groups in 2019 and 2020. In 2019, simple sugar intake was significantly higher in the non-abdominal obesity group than in the abdominal obesity group; however, there was no significant difference between the groups in 2020. Although not shown in the table, the frequency of alcohol consumption and eating out increased among men during the pandemic, and a direct relationship between these factors and abdominal obesity could not be confirmed. This study focused on PA and energy intake, in terms of energy consumption and intake. Nevertheless, a detailed analysis of lifestyle factors is required in the future.

Among the different behavioral domains in the GPAQ, recreational moderate-intensity PA was higher in the non-abdominal obesity group than in the abdominal obesity group in 2019; however, this difference was not confirmed in 2020. In addition, there was no difference in recreational vigorous-intensity PA in 2019 with respect to the presence or absence of abdominal obesity; however, a significant difference was confirmed in 2020. This means that men without abdominal obesity actively engaged in recreational activities. However, this could not be confirmed using the KNHANES data. Nevertheless, considering that there were relatively fewer restrictions on vigorous-intensity recreational activities that could be performed outdoors during the pandemic, the difference in results could be considered to depend on the type of recreational activity. According to the 2020 National Sports Participation Survey, COVID-19 had an impact on the participation rate in sports. As of 2019, the sports that Koreans mainly participated in in 2020 were walking, mountain climbing, and bodybuilding. The participation rate in indoor sports activities, such as bodybuilding and swimming, tended to decrease, while that for outdoor sports activities, such as climbing and cycling, tended to increase[38].

Moderate-intensity occupational PA before and after COVID-19 was higher in the abdominal obesity group than in the non-abdominal obesity group. This is expected to vary depending on the individual's economic situation or occupation. According to a study that analyzed the prevalence of obesity and abdominal and social factors in Korea from 2009 to 2018[39], the prevalence of obesity and abdominal obesity was higher in individuals with low household income. Furthermore, there was a higher prevalence of obesity and abdominal obesity among managers and individuals who worked longer hours in split and night shifts.

The number of days of walking and strength training per week was greater in the non-abdominal obesity group than in the abdominal obesity group both before and after the COVID-19 pandemic. Analysis of the relationship between abdominal obesity and the number of days of walking and strength training per week showed that only the number of days of strength training differed according to the presence or absence of abdominal obesity. Furthermore, the results of the analysis of the association between abdominal obesity and the number of days of walking, strength training, and aerobic exercise indicated that only the number of days of strength training per week had the strongest association with abdominal obesity.

Nevertheless, in the abdominal obesity group in 2020, the rate of no strength training was higher than that in 2019. As mentioned above, the COVID-19 pandemic has changed the participation rate of Koreans in sports, the most notable of which is a decrease in participation in bodybuilding[37]. Bodybuilding is an activity in which people participate in strength training; however, in the early stages of the pandemic, it was difficult to participate in such activities due to the closure of public sports facilities and ban on intermittent gatherings in private gymnasiums and fitness centers. Public strength training equipment installed outdoors is not a crowded place where infection can spread; however, its nonuse can be attributed to the high risk of infection as it is used by an unspecified number of people.

Thus, it can be predicted that even if there is a change in the amount of PA, such as walking or aerobic exercise, due to the influence of social distancing measures, strength training at least once per week is effective in suppressing abdominal obesity, regardless of COVID-19. The importance of strength training was confirmed in a previous study[40] comparing PA according to abdominal obesity in Korean men in their 20s and 30s, and their results also showed a relationship between strength training and abdominal obesity rather than walking and aerobic exercise. The result that strength training is effective in suppressing abdominal obesity is meaningful not only in daily life but also during pandemics, such as COVID-19. Nevertheless, since obesity is determined by energy consumption through physical activity in various domains and energy intake rather than participation in a certain type of exercise, strength training is not the only type of exercise that improves abdominal obesity. However, our findings are meaningful because most PA recommendations for preventing or treating obesity focus on aerobic exercise. Despite the mixed results on the effect of strength training on obesity, sufficient evidence supports the notion that regular strength training is effective in promoting weight loss in obese individuals. Strasser and Wolfgang[41], in their review article, provided strong evidence that regular strength training can effectively alter body composition[42-44], including decrease in visceral fat in obese men, independent of dietary restrictions[45-48]. Moreover, changes in strength-training-associated positive body composition can be maintained after completion of the supervised exercise regime[44].

However, this study has some limitations. First, as KNHANES is a cross-sectional study, it is difficult to establish a causal relationship. Second, we did not control for potential confounding variables that could affect PA and energy intake, such as sex, stress level, and household type. Third, since the findings of the study indicate changes over a relatively short period of one year following the COVID-19 pandemic, there may be additional changes in PA and energy intake during the ongoing COVID-19 pandemic. Despite these limitations, our findings can be generalized to health behavioral trends in Korean men with abdominal obesity, because they are based on large-scale national KNHANES data.

In conclusion, during the COVID-19 pandemic, there was an increase in body weight, BMI, and WC among Korean men and a decrease in PA in areas affected by social distancing measures, such as aerobic exercise and walking days. Strength training was the strongest health behavior affecting the presence or absence of abdominal obesity in men. Regardless of the COVID-19 pandemic, strength training at least once per week suppressed abdominal obesity in 2019 and 2020. Thus, the importance of strength training should be further emphasized not only for the prevention of abdominal obesity in men but also for men who are already abdominally obese.

This study is meaningful in that it confirmed the usual participation type in PA and the number of days of practice required to obtain a positive effect according to the presence or absence of abdominal obesity. Therefore, if the number of people participating in strength training is increased by promoting the importance of strength- training and developing and distributing effective programs, it will have a positive impact on public health. In addition, the results of this study can provide a basis for the development of interventions for abdominal obesity and future infectious diseases.

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