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Original Research

Relationship between cardiovascular disease risk factors, health behavior and physical fitness according to visceral fat in older men

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Abstract

Background: Obesity in older adults is increasing. The two types of fat involved in obesity are subcutaneous and visceral fat. We investigated the relationship between cardiovascular risk factors, health-related behaviors, and physical fitness based on the level of visceral fat in older men. **Methods**: Data from 1219 men aged ≥65 years who underwent health checkups at Korean hospitals from 2012 to 2020 were analyzed. Computed tomography (CT) data was used to divide participants into low visceral fat area (LVFA) and high visceral fat area (HVFA) groups. Cardiovascular risk factors such as blood pressure, triglyceride level, high-density cholesterol, and fasting blood glucose were measured. Bio-impedance analysis was used for body composition, and arteriosclerosis was tested by brachial artery pulse wave velocity (baPWV). Physical activity, exercise type, smoking, and alcohol consumption were investigated and cardiorespiratory fitness, grip strength, leg strength, flexibility, balance, and agility were determined. The odds ratio (OR) of HVFA was calculated by logistic regression analysis. **Results**: HVFA and LVFA groups exhibited significant differences in waist circumference, systolic blood pressure, triglyceride, glucose, baPWV, weekly physical activity, aerobic exercise, and alcohol consumption. Compared to the high fitness group, the low fitness group had an increased OR for HVFA; cardiorespiratory fitness (OR 3.563), grip strength (OR 2.365), leg strength (OR 4.145), and flexibility (OR 2.523). The group with low aerobic and strength training frequency increased OR by 2.5 and 3.2 times compared to the low frequency group, respectively. The OR of HVFA increased 2.8 times in the group which consumed alcohol more than 4 days a week compared to the group with consumption less than monthly. **Conclusions**: Men with HVFA exhibited lower levels of physical activity, more alcohol consumption, and lower levels of fitness than those with LVFA. Moreover, low levels of fitness, physical activity, and high alcohol consumption increased the risk of HVFA.

Keywords: Visceral fat; Cardiovascular disease; Physical activity; Fitness; Odds ratio

1. Introduction

Advances in medicine and science have increased the life expectancy of humans, but the increase in sedentary lifestyles and lack of physical activity are contributing to the increased prevalence of lifestyle-related diseases [1]. The population of older adults is rapidly increasing worldwide; for example, in the United States, the number of individuals aged 65–85 years is expected to increase by 147% and 389%, respectively, by 2030 [2].

A typical phenomenon associated with aging is a increasing in the body composition, but a decrease in fitness, such as cardiorespiratory fitness and strength [3]. Muscle mass decreases by 0.1 to 0.5% every year after the age of 30 years, and the rate of decline rapidly increases after the age of 65 years, at which point it is accompanied by a decrease in muscle strength [4]. Contrarily, body fat is known to increase with age [5]. These changes contribute to an increased risk of cardiovascular disease in older people; it is predicted that 40% of the individuals in this population will die from cardiovascular disease by 2030 [6].

Body fat is divided into visceral fat area (VFA) and subcutaneous fat, with visceral fat having a larger effect on cardiovascular disease than subcutaneous fat in terms of abdominal obesity [7,8]. One previous study, reported that visceral fat independently increases the risk of cardiovascular disease regardless of the amount of total body fat, with the risk of mortality increased by 1.13 times in women with high visceral fat [9]. Furthermore, in the brachial-ankle pulse wave velocity (baPWV) study performed as a predictive test for atherosclerosis, Kim *et al*. [10] reported that baPWV was correlated with VFA in a large-scale study, but it was not significant with body mass index (BMI) and waist circumference.

Therefore, visceral fat is considered a major risk factor for cardiovascular disease, the typical method for reducing visceral fat is diet and exercise [11]. In particular, it is important to reduce visceral fat through increased physical activity in order to improve the decrease in muscle mass and increase in body fat due to aging [12]. Zhang *et al*. [13] showed a decrease in VSF from 15.3 to 19.3 cm^2 in obese women through 12 weeks of high intensity training. Kobayashi *et al*. [14] reported that a significantly higher VFA in low physical activity compared to high physical. Moreover, several studies have reported that physical activity reduces body fat, increases firmness, and positively impacts blood flow baPWV [14,15]. In 12-month experimental study, baPWV was significantly improved in the physically active group [15]. In the study of physical activity and baPWV in the elderly, the active group was 1758.1 cm/sec, but the inactive group was 1969.7 cm/sec, with a significant difference [16].

Although physical activity is accompanied by improvement in cardiovascular health [17], studies on visceral fat, physical activity, and physical strength using large-scale computed tomography CT in the elderly are limited. However, large-scale studies conducted in older populations are limited. Therefore, this study aimed to analyze cardiovascular disease risk factors, health behaviors, and physical fitness based on the amount of visceral fat in older adults aged ≥65 years.

2. Materials and methods

2.1 Participants

This study was conducted on 3332 older men aged ≥65 years who underwent medical examination at a general hospital health examination center located in Seoul, Korea. The data collection period was set for a total of 8 years from January 2012 to January 2020. The participants were older men whose visceral fat was measured using abdominal computed tomography (CT) scanning, underwent tests of all cardiovascular risk factors, measured physical fitness, and completed the questionnaire including physical activity, smoking, and alcohol consumption. Men who did not consent to provide research data and those who did not complete the required tests were excluded. A total of 1219 participants were analyzed (Fig. 1). The purpose of the tests and the use of the results for the purpose of research were explained. The data of those who provided written informed consent were used in the analysis. The study was approved by the research ethics committee of the Asan medical center (Approval number 2020-0918).

2.2 Anthropometric and body composition

Body composition analysis was performed using Inbody-720 equipment (Biospace, Seoul, Korea). Body composition analysis was conducted using the bioelectrical impedance analysis (BIA) method. The participant fasted for 8 hours prior to the test. The temperature of the test room was maintained at 20–25 °C, and participants did not wear jewelry such as rings, watches, or chains. Height, weight, body mass index (BMI), body fat mass, and body fat percentage were measured. In addition, the waist circumference was measured using a tape measure at a level 2 cm above the umbilicus and without pressure on the subcutaneous tissue.

2.3 Blood sample and blood pressure

Blood sample (25–30 mL) was obtained via the median cubital vein. Biochemical parameters such as levels of fasting glucose, total cholesterol (TC), triglyceride (TG), high density lipoprotein (HDL), and low density lipoprotein (LDL) related to cardiovascular disease were analyzed. Blood pressure was measured using a mercury sphygmomanometer. The lower end of the cuff was placed 3 cm above the crease of the elbow and the size of the cuff was selected to cover 2/3 of the upper arm. The brachial artery of the right arm was palpated and the cuff inflated to maximum pressure at a rapid and constant rate with the ear insertion section of the stethoscope facing forward. The valve was adjusted so that the pressure declined uniformly at a rate of 2 mmHg per second. The point at which the Korotkoff sound first occurred was recorded as the systolic blood pressure and the Korotkoff before the sound gradually decreased and disappeared was recorded as the diastolic blood pressure.

2.4 Visceral fat

Visceral fat was measured using a CT machine (Somatom Definition Flash equipment, Siemens Healthcare, Germany) by scanning the L4–5 lumbar vertebrae. The entire image data was obtained using the raw data of the non-contrast abdominal CT scan. The visceral fat was quantitatively measured by radiologists using data obtained from CT. The participants were classified into low visceral fat (LVFA) and high visceral fat (HVFA) groups based on the visceral fat area cutoff value of 103.8 cm^2 (the diagnostic criterion for visceral fat obesity in Korea) as reported by Kim *et al*. [18].

2.5 Brachial-ankle pulse wave velocity

The measuring equipment used to examine arteriosclerosis in this study was a blood flow pulse wave test device (BP-203RPEIII, Omron Healthcare, Japan). The brachial-ankle pulse wave velocity (baPWV) was measured, which can determine the degree of hardening of blood vessels. The participant was placed in the supine position and the upper arm and ankle area were measured. The PWV was calculated by dividing the blood vessel length by the time difference of pulse wave transmission.

2.6 Health-related survey

Participants recorded the level of physical activity in a health-related questionnaire that examined items such as alcohol, smoking, and physical activity before the examination. The level of physical activity was divided three categories, vigorous, moderate, and low physical activity, using the international physical activity questionnaire provided by the World Health Organization [19]. This was converted into metabolic equivalents (METs) and the amount of physical activity per week was calculated by examining the number of times per week and the duration of physical activity. The participants' weekly metabolic rate was calculated by multiplying the weekly activity time by the METs according to each physical activity. In order to confirm detailed information, a questionnaire was conducted to

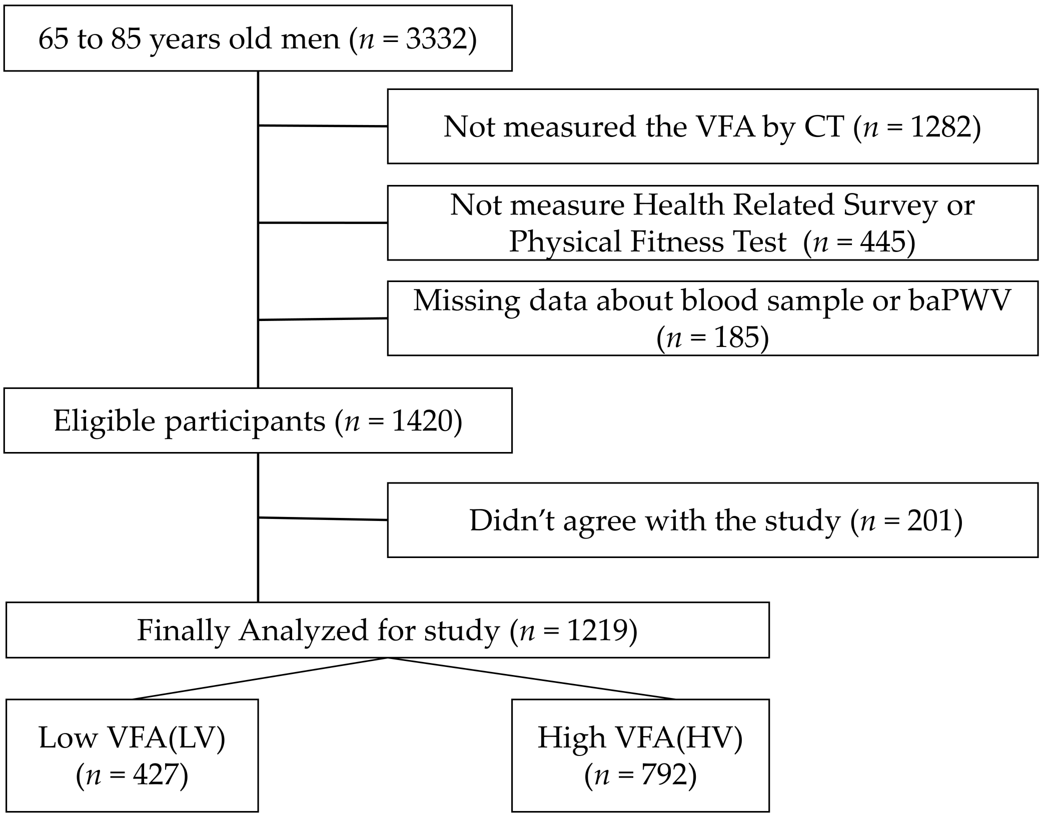

Fig. 1. Participant's inclusion and exclusion criteria diagram.

distinguish between aerobic exercise and strength exercise. In the smoking, a survey was conducted in which one of the three categories (never, quit, or present) was selected. Regarding drinking, one of four options was selected (<once per month, 2–4 times per month, 2–3 times per week, or ≥4 times per week).

2.7 Physical fitness test

For the physical fitness test, Helmas comprehensive physical fitness measurement equipment (Kowells Co., Seoul, Korea) was used, and grip strength representing upper extremity strength, isometric leg extension representing lower extremity strength, cardiorespiratory fitness (CRF), flexibility, agility, and balance were measured [20]. The grip strength test was performed with the second joint of the finger touching the grip of the dynamometer. The back was kept straight, and the participant looked straight ahead. The arms were abducted about 30° and the elbows were not bent. When signaled by the examiner, the dynamometer was grasped with maximum force for 5 s. Left side testing was performed followed by right side testing, and after measuring parameters twice for each side, the better value was recorded. Isometric leg extension was measured by lower extremity strength. This was done by placing both feet under the leg strength tester pad and securing the dorsum of the foot. When the examiner signaled, the participant pushed both legs forward as far as possible. Two measurements were taken and the better value was recorded. Cardiorespiratory fitness was assessed by the Astrand–Ryhming 6-minute cycling test. After starting the test at a load of 50 watts and a speed of 60 revolutions per minute, after 1 min, the load was increased to 100 watts or 150 watts based on the participant's physical condition. Maximum oxygen intake was calculated by recording maximum heart rate during exercise for 6 mins. Flexibility was measured by placing both feet in the shape of a footrest with both knees fully extended and measuring the distance (cm) by bending the participant's back and placing their fingertips side by side with toes. For agility, the participant stood on a stool with their feet shoulder-width apart. When the light was turned on together with the beeping sound of the lamp, the reaction time was measured by inspecting it in place as quickly as possible. Balance was tested by making the participant stand on one foot with eyes closed. The better values were recorded by examining the left and right feet twice each. To ensure the accuracy of the test, the temperature of the test room was maintained at Celsius 20–22°, and the humidity was maintained at 60%. Additionally, participants wore comfortable and loose-fitting clothes.

2.8 Data analysis

The general characteristics, comparisons between groups and odds ratio (OR) were analyzed using SPSS 25.0 (IBM SPSS, Armonk, NY, USA), and MedCalc 17.9 (Med-

Calc Software, Ostend, Belgium) was used for receiver operating characteristic (ROC) curve. Normality tests were performed using Kolmogorov–Smirnov and Shapiro–Wilk methods, and the variables appeared nonparametric. For continuous variables, Mann–Whitney test, and categorical variables, chi-square tests were performed. After classifying the groups into upper and lower groups based on the cutoff shown through the ROC curve, a chi test was performed, and the prevalence of the subgroup was calculated using logistic regression analysis to calculate the OR. The OR according to fitness and physical activity amount was divided into high, medium, and low groups using the tertile. In addition, The OR according to health behavior was calculated. Model 1 used age as the adjusted variable, and Model 2 included age and multi variables. The significance level was set at $p < 0.05$.

3. Results

3.1 General characteristics

Table 1 shows the general characteristics of participants. According to the amount of visceral fat in the elderly, they were classified into low visceral fat area (LVFA) and high visceral fat area (HVFA), and there were significant differences in body composition such as height, weight, and BMI, and waist circumference, systolic blood pressure, triglyceride, HDL cholesterol, blood glucose, and baPWV and ankle PWV, as a risk factor for cardiovascular disease were significantly different. In addition, in the physical fitness, there were significant differences in cardiorespiratory fitness, leg strength, grip strength, flexibility, and balance, along with significant differences in the weekly physical activity level.

3.2 Ratio of exercise type and health related style for low and high VFA groups

Table 2 shows the results of the cross-analysis on health-related behaviors such as exercise type, alcohol consumption, and smoking between LVFA and HVFA groups. In the aerobic exercise during physical activity, the LVFA group showed a significant practice rate, and alcohol intake was also found to be less in the LVFA group. There was no statistical significance between strength exercise and smoking.

3.3 Cut-off value of fitness factor and physical activity to decrease the VFA

Table 3 shows the cut-off values of the physical fitness for visceral fat obesity; cardiorespiratory fitness (28.8 mL/kg/min), leg strength (1.27 kg/BW), grip strength (0.51 kg/BW), flexibility (–1.8 cm), balance (5 sec), physical activity (1840 METs-min/week) levels. However, there was no statistical significance in the agility. Odds ratio was analyzed by classifying each variable into an upper group and a lower group according to cut-off value. The prevalence increased by 1.841 times in CRF, 3.287 times in leg strength, 2.485 times in grip strength, 4.941 times in flexibility, and 2.444 times in PA in the lower value group.

3.4 VFA obesity prevalence according to physical fitness, physical activity

Table 4 shows the odds ratio (OR) of each variable related to the prevalence of visceral fat obesity. The prevalence was determined by classifying each variable into three groups: high, medium, and lower tertile. Prevalence increased in the low fitness or physical activity group compared to high group; It increased 3.563 times in CRF, 4.145 times in leg strength, 2.365 times in grip strength, 2.523 times in flexibility, and 3.458 times in physical activity. There were no significant prevalence values in agility and balance.

3.5 Visceral fat obesity prevalence according to exercise type and health related style

Table 5 shows the OR for the prevalence of visceral fat obesity according to exercise type and health-related behavior. In the exercise type, when a person who performed aerobic exercise 5 to 7 times per week was set as a reference, the probability of developing visceral fat obesity was 2.583 times higher in participants who exercised 0 to 2 times per week, which was statistically significant. However, there was no statistical significance in the aerobic exercise 3–4 times per week. And the prevalence was increased by 3.241 times in the group doing strength training 0–1 days per week compared to the group doing 4–7 days per week. Regarding health-related behaviors, the prevalence of visceral fat obesity according to smoking was not statistically significant, but in relation to alcohol intake, the group drinking 2 to 3 times a week was showed an odds ratio of 1.841, and in the group drinking 4 or more times a week, an odds ratio of 2.889 was shown, showing a statistically significant result.

4. Discussion

Visceral fat increases with age, and research has shown that the proportion of body fat changes from subcutaneous fat to visceral fat after middle age [21]. In addition, it has also been reported that visceral fat independently increases the risk of cardiovascular disease regardless of the quantitative status of total body fat [22–24]. This study investigated the relationship between cardiovascular risk factors according to the level of visceral fat and physical activity, health-related behaviors and physical fitness related to the amount of visceral fat. In a comparative analysis between the group with LVFA and the group with HVFA, the risk factors for cardiovascular disease, such as waist circumference, systolic blood pressure, triglyceride, high-density cholesterol, blood sugar, and baPWV, were investigated. The LVFA group showed low values in all items except diastolic blood pressure. The metabolic characteristics of visceral fat are related to these cardiovascular and disease-inducing risk factors [25]. The basal lipoly-

Table 1. General characteristics of the study participants.

Variables	LVFA (n = 427)	HVFA (n = 792)	*p*-value	Effect size
Age, years	68.8 ± 3.8	70.0 ± 4.9	0.245	0.051
Height, cm	169 ± 3.5	167.8 ± 5.3	<0.001*	0.001
Weight, kg	62.0 ± 6.3	70.2 ± 8.0	<0.001*	0.140
BMI, kg/m^2	23.7 ± 2.2	27.9 ± 2.6	<0.001*	0.114
VFA, cm^2	88.11 ± 23.44	168.83 ± 51.54	<0.001*	0.592
Cardiovascular disease risk factor				
Waist circumference, cm	84.3 ± 6.0	91.5 ± 6.3	<0.001*	0.297
SBP, mmHg	121.0 ± 15.0	129.5 ± 11.4	0.015*	0.045
DBP, mmHg	79.5 ± 10.2	81.2 ± 8.8	0.394	0.001
TG, mg/dL	96.4 ± 52.7	132.2 ± 63.5	0.004*	0.331
HDL, mg/dL	55.8 ± 11.9	50.3 ± 13.3	0.033*	0.060
Glucose, mg/dL	106.5 ± 30.6	118.6 ± 26.1	0.021*	0.087
baPWV, cm/sec	1533.2 ± 332.6	1819.5 ± 422.8	<0.001*	0.195
Fitness				
CRF, mL/kg/min	29.2 ± 4.3	28.0 ± 5.1	0.023*	0.029
Leg strength, kg/BW	1.36 ± 0.38	1.16 ± 0.87	0.011*	0.240
Grip strength, kg/BW	0.63 ± 0.11	0.57 ± 0.22	0.045*	0.035
Flexibility, cm	3.2 ± 7.3	–3.2 ± 9.5	<0.001*	0.215
Agility, ms	343.5 ± 128.8	358.6 ± 99.6	0.466	0.033
Balance, s	7.3 ± 6.3	5.2 ± 4.4	0.037*	0.030
Physical activity, Mets-min/week	2117.1 ± 513.6	1667.6 ± 314.5	0.014*	0.012

* $p < 0.05$. Abbreviations: LVFA, low visceral fat area; HVFA, high visceral fat area; BMI, body mass index; VFA, visceral fat area; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL, high-density cholesterol; baPWV, brachial ankle pulse wave velocity; CRF, cardiorespiratory fitness.

Table 2. Low VFA and high VFA ratio of categorized variables.

Variables	Group	LVFA (n = 427)	HVFA (n = 792)	χ^2	*p*-value	Effect size
Aerobic exercise, *n* (%)	5–7 days/week	139 (32.6%)	145 (18.3%)	14.257	0.011*	0.295
	3–4 days/week	165 (38.7%)	253 (32.0%)			
	0–2 days/week	123 (28.7%)	394 (49.7%)			
Strength exercise, *n* (%)	4–7 days/week	109 (25.5%)	113 (14.3%)	1.372	0.088	0.182
	2–3 days/week	98 (22.9%)	203 (25.6%)			
	0–1 days/week	220 (51.6%)	476 (60.1%)			
Smoking status, *n* (%)	Never	110 (25.8%)	249 (31.4%)	0.496	0.628	0.068
	Quit	275 (64.5%)	471 (59.5%)			
	Present	42 (9.7%)	72 (9.1%)			
Alcohol consumption, *n* (%)	≤1 time/month	163 (38.2%)	231 (29.2%)	12.096	0.031*	0.212
	2–4 times/month	154 (36.1%)	221 (27.9%)			
	2–3 times/week	77 (18.0%)	207 (26.1%)			
	≥4 days/week	33 (7.7%)	133 (16.8%)			

* $p < 0.05$. Abbreviations: LVFA, low visceral fat area; HVFA, high visceral fat area.

sis rate of adipocytes is higher in visceral adipocytes, and the sensitivity to the lipolysis inhibitory action of insulin is low [26]. Therefore, people with a lot of visceral fat have higher fasting blood sugar [27]. Taniguchi reported a positive correlation between visceral fat mass and fasting blood glucose level in normal type 2 diabetes patients [28]. In addition, more angiotensinogen mRNA enzyme is expressed in visceral adipose tissue than in subcutaneous fat, which increases the risk of hypertension [29]. Chiba reported on the prevalence of visceral fat mass and cardiovascular risk factors in 353 men with an average age of 62.8 years [30]. In his study, compared with participants with low visceral fat, participants with high visceral fat had a 3.45 times higher odds ratio for hypertension and a 3.74 times higher risk of developing hypertriglyceridemia. Sato also reported that those with high visceral fat had statistically significant differences in fasting blood sugar levels, triglycerides, high-density cholesterol, and arteriosclerosis

Table 3. Cut off value and odds ratio of fitness factor and physical activity to decrease the VFA.

Variables	Cutoff	AUC	Specificity	Sensitivity	*p*-value	OR (95% CI)
CRF, mL/kg/min	28.8	0.624	67.1	77.4	0.038*	1.841 (1.028–3.095)*
Leg strength, kg/BW	1.27	0.675	73.9	64.3	0.025*	3.287 (1.483–7.284)*
Grip strength, kg/BW	0.51	0.632	72.1	73.6	0.012*	2.485 (1.406–5.694)*
Flexibility, cm	–1.8	0.709	64.1	71.0	0.016*	4.941 (1.902–8.833)*
Agility, ms	370	0.581	79.9	65.2	0.138	1.968 (0.795–4.872)
Balance, s	5.0	0.575	66.2	70.1	0.024*	1.533 (0.684–3.436)
PA, METs-min/week	1840	0.589	63.4	58.1	0.020*	2.444 (1.082–5.519)*

* $p < 0.05$. Abbreviations: OR, odds ratio; CI, confidence interval; AUC, area under the curve; CRF, cardiorespiratory fitness; BW, body weight, PA, physical activity.

Table 4. VFA obesity prevalence according to physical fitness, physical activity.

Variables	Group	Model 1			Model 2		
		OR	95% CI	*p*-value	OR	95% CI	*p*-value
CRF	High	1	-	-	1	-	-
	Medium	1.240	0.846–2.412	0.350	1.947	0.811–4.676	0.136
	Low	2.410	0.940–4.510	0.041*	3.563	1.134–5.191	0.030*
Leg strength	High	1	-	-	1	-	-
	Medium	1.854	0.554–4.410	0.185	2.269	0.881–5.841	0.090
	Low	2.840	1.104–6.010	0.009*	4.145	1.511–11.37	0.006*
Grip strength	High	1	-	-	1	-	-
	Medium	1.129	0.740–1.952	0.652	1.558	0.577–4.209	0.382
	Low	2.098	0.849–4.210	0.121	2.365	1.230–6.012	0.021*
Flexibility	High	1	-	-	1	-	-
	Medium	1.110	0.881–3.100	0.258	1.523	0.649–3.570	0.135
	Low	2.098	0.465–3.011	0.419	2.523	1.649–5.578	0.034*
Agility	High	1	-	-	1	-	-
	Medium	1.524	0.751–3.640	0.716	1.346	0.559–3.244	0.508
	Low	1.659	0.860–3.510	0.504	1.937	0.659–5.694	0.230
Balance	High	1	-	-	1	-	-
	Medium	0.849	0.591–3.114	0.810	1.022	0.652–2.174	0.098
	Low	0.998	0.434–3.108	0.411	0.903	0.499–1.996	0.217
PA	High	1	-	-	1	-	-
	Medium	1.080	0.691–3.254	0.403	1.108	0.769–5.779	0.147
	Low	2.110	1.253–4.510	0.022*	3.458	1.563–8.777	0.018*

* $p < 0.05$. Abbreviations: CI, confidence interval; CRF, cardiorespiratory fitness; PA, physical activity.

Model 1: adjustment variables included age.

Model 2: adjustment variables included age, smoking, alcohol.

among 347 participants [31]. In this study, systolic blood pressure, triglycerides, high-density cholesterol, and fasting blood sugar showed the same results. In particular, the difference in the pulse wave velocity of the upper arm and ankle, which is a major factor in cardiovascular disease, was evident. Because the arteries are elastic and composed of a soft inner surface, blood circulation occurs efficiently. When arterial wall stiffness appears, the elasticity of the arterial walls decreases, which leads to cardiovascular disease [32]. Pulse wave velocity is a very useful test to evaluate and predict the risk of cardiovascular disease. The normal range for the baPWV is 1500~1800 cm/s for men and 1300–1500 cm/s for women. Both men and women are considered to be at high risk of atherosclerosis if they are above 1800 cm/s [33]. In this study, the average of baPWV was investigated according to the high and low of visceral fat. The average of 1533.2 cm/s in the LVFA group and 1819.5 cm/s in the HVFA group was statistically significant. In particular, the HVFA group was at a level that could be diagnosed with arteriosclerosis.

In addition, many previous studies have shown that people with a lot of physical activity had less visceral fat distribution [34–37]. The musculoskeletal changes that occur with age increase the risk of falls and fractures which results in a decrease in exercise capacity, and the risk of death is increased by decreasing independence which causes var-

Table 5. Visceral fat obesity prevalence according to exercise type and health related style.

Variables	Group	Model 1			Model 2		
		OR	95% CI	*p*-value	OR	95% CI	*p*-value
Aerobic exercise	5–7 days/week	1	-	-	1	-	-
	3–4 days/week	1.002	0.745–3.411	0.248	1.021	0.360–2.892	0.196
	0–2 days/week	1.941	1.093–4.054	0.012*	2.583	1.566–4.426	0.031*
Strength exercise	4–7 days/week	1	-	-	1	-	-
	2–3 days/week	1.591	0.419–3.978	0.094	2.259	0.940–5.427	0.068
	0–1 days/week	2.941	0.598–4.471	0.087	3.241	1.228–6.316	0.005*
Smoking status	Never	1	-	-	1	-	-
	Quit	1.098	0.784–3.195	0.259	1.258	0.311–6.849	0.143
	Present	1.254	0.896–4.910	0.211	1.778	0.782–8.333	0.135
Alcohol consumption	≤1 time/month	1	-	-	1	-	-
	2–4 days/month	1.087	0.564–3.580	0.897	1.097	0.316–3.816	0.884
	2–3 days/week	1.346	0.874–4.031	0.201	1.841	0.884–4.486	0.017*
	≥4 days/week	2.149	1.216–5.011	0.026*	2.889	1.309–5.567	<0.001*

* $p < 0.05$. Abbreviations: CI, confidence interval.

Model 1: adjustment variables included age.

Model 2: adjustment variables included age, fitness and physical activity.

ious diseases due to a decrease in physical activity [38]. In addition, the amount of strength-based exercise was not statistically significant with the prevalence of visceral fat obesity; of the two exercise types, only sufficient aerobic exercise prevented visceral fat obesity. In addition, dividing physical activity into higher and lower level categories when examining the OR value showed a statistically significant result of 2.444. However, as a result of examining the OR by dividing it into three grades (high-medium-low), the OR value of medium level physical activity was 1.108, which was not statistically significant. This may mean that even moderate physical activity can lower the prevalence of visceral fat obesity.

Molenaar studied the relationship between alcohol intake and visceral and subcutaneous fat in 2926 participants and found that, in men, the group who consumed 14 or more drinks per week showed a higher VFA than the group that did not, but there was no statistical difference in subcutaneous fat [35]. In this study, the cross-analysis result and odds ratio were statistically significantly higher in the group that consumed alcohol 2–3 times or more per week than the group that did not. Miyatake studied the relationship between visceral fat and physical fitness in the Japanese population [39]. In his study, the maximum oxygen intake, grip strength, leg strength, and flexibility were measured in the normal group and in the visceral fat obesity group, and there were statistically significant differences in the maximum oxygen intake and leg muscle strength. However, his study involved participants aged 38 to 65 years (mean 51.2 $\pm$ 7.2). The participants of this study were people ≥65 years old, and there were statistically significant differences in cardiorespiratory fitness, grip strength, leg strength, flexibility, and balance. Visceral fat obesity is thought to be a phenomenon caused by a lack of physical activity due to aging. Further, in this study, participants with statistically significant prevalence of visceral fat obesity were analyzed for cardiorespiratory fitness, grip strength, leg strength, and flexibility in odds ratio according to physical fitness. In particular, the OR of flexibility was 4.941, which had the highest statistical significance. This result is also considered to be related to regular physical activity. In the elderly, as the elastic tissue deteriorates or the contractile state continues for a long time, collagen tissue adhesion occurs easily, reducing the mobility and flexibility of the skin, muscle, and tendon tissue [40,41]. As a result, the range of motion of all joints is reduced, incorrect posture is created, and the risk of disease or injury increases [42]. Therefore, regular physical activity prevents visceral fat and maintains or increases physical fitness. The cut-off values of each physical fitness item to prevent visceral fat obesity were 28.8 mL/kg/min for cardiorespiratory fitness, 0.51 and 1.27 kg/BW for grip and leg strength, respectively, flexibility –1.6 cm, and balance 5 sec.

The cutoff and OR values derived from the results of this study are meaningful in providing specific information on fitness and physical activity to patients who visit for the purpose of preventing and treating visceral obesity. Therefore, it will be useful to suggest practical physical fitness values and physical activity values supported by experts for improvement programs to be provided to visitors. For example, the cut-off value of the amount of physical activity to prevent visceral fat obesity investigated in this study was 1840 METs-min/week. If walking exercise is considered to be about 4 METs, 460 minutes of walking exercise per week is required for preventing visceral fat obesity in elderly. Nevertheless, the limitation of this study is that the causal relationship between visceral fat obesity, physical fitness, and health behavior cannot be confirmed due to the cross-sectional design. In addition, there was no comparison between subcutaneous fat and visceral fat, and women's data were not included. Lastly, the CT scan used to measure the amount of visceral fat is relatively expensive, so there is a limit to its popularization. Therefore, additional research using relatively simple and cost-effective equipment will be required.

5. Conclusions

Men with higher visceral fat had lower physical activity, higher drinking frequency, and lower fitness levels. The risk of visceral fat increased 3.5-fold at low CRF, 4.1-fold at low leg strength, and 2.3-fold at low grip strength. Further, low physical activity increased 3.4 times. Therefore, to reduce the accumulation of visceral fat, it may be effective to increase physical activity and improve various physical fitness.

Author contributions

Conceptualization—YHK and DHK; methodology—DHK; formal analysis—DHK and JKH; investigation—DHK; original draft writing—YHK and DHK; review and editing—DHK and JKH; supervision—YHK and JKH. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the research ethics committee of the Asan medical center (Approved number 2020-0918). All included participants provided written informed consent.

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Conflict of interest

The authors declare no conflict of interest.

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