Heliyon 7 (2021) e06264

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Correlation of body visceral fat rating with serum lipid profile and fasting blood sugar in obese adults using a noninvasive machine

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ARTICLE INFO

Keywords:
Obesity
Non-invasive machine
Visceral fat
Serum lipid profile
Fasting blood sugar

ABSTRACT

Increased visceral fat is associated with an increased mortality rate. Bioelectrical impedance analysis (BIA) is a noninvasive method to assess visceral fat that is easily accessible and avoids exposure to radiation. It is unknown how a visceral fat rating from a noninvasive machine correlates with the serum lipid profile and fasting blood sugar (FBS). The aim of this research is to study the correlation of the visceral fat rating obtained by a noninvasive method with the serum lipid profile and FBS. This cross-sectional study involved 90 obese adults, ranging in age from 18 to 60 years old. The visceral fat rating was measured by BIA. The results demonstrated that significant positive correlations were found between the serum triglycerides and visceral fat rating ($r = 0.287$, $P = 0.006$) and between the FBS and visceral fat rating ($r = 0.210$, $P = 0.047$). There was a negative correlation between the serum high-density lipoprotein (HDL) cholesterol and visceral fat rating ($r = -0.322$, $P = 0.002$). In conclusion, statistically significant positive correlations were found between the serum triglycerides and visceral fat rating and between the FBS and visceral fat rating, and a negative correlation was found between the serum HDL-cholesterol and visceral fat rating.

1. Introduction

Obesity is a major problem worldwide because it is associated with cardiovascular events and increases mortality rates. Obesity is caused by excessive adipose tissue, and the pathogenesis is due to a positive energy balance (energy intake > energy expenditure) [1]. Furthermore, obesity is associated with vascular and metabolic dysfunction. These physiological effects lead to the development of a range of morbidities, including cardiovascular disease, coronary heart disease, cerebral infarction, diabetes mellitus type 2, hypertension, dyslipidemia, obstructive sleep apnea (OSA), gastroesophageal reflux disease (GERD), osteoarthritis of the knee, carpal tunnel syndrome and cancer [2, 3, 4].

The most common method for diagnosing obesity is the body mass index (BMI), which is calculated as one's weight in kilograms divided by one's height in meters squared (kg/m^2) [5]. There are two criteria for diagnosing obesity: the Regional Office for the Western Pacific (WPRO) standard and World Health Organization (WHO) definition. The WPRO definition classifies overweight as BMI 23.0–24.9 kg/m^2, class I obesity as BMI 25.0–29.9 kg/m^2 and class II obesity as BMI ≥30.0 kg/m^2. The WHO classification defines overweight as BMI 25.0–29.9 kg/m^2, class I obesity as BMI 30.0–34.9 kg/m^2, class II obesity as BMI 35.0–39.9 kg/m^2 and class III obesity as BMI ≥40.0 kg/m^2 [6].

The prevalence and trend of obesity is increasing worldwide. Since 1991, the prevalence of obesity has increased by 65% in men and 25% in women. Current trends indicate that by 2050, 60% of males and 50% of females worldwide will be obese [7]. Data from the Thai National Health Examination Survey show that the prevalence of obesity class I (BMI 25–29.9 kg/m^2) and class II (BMI ≥30.0 kg/m^2) in Thai adults aged ≥20 years were 26.0% and 9.0%, respectively [8].

However, BMI is the most common method for assessing obesity, but it is a suboptimal method for assessing cardiovascular and metabolic disease. In this regard, the waist circumference measurement has been shown to aid the BMI, improving the risk assessment in screening cardiovascular disease and metabolic disease at any BMI level [9, 10]. Excess visceral adipose tissue is causally related to cardiovascular and metabolic diseases and may be a marker of dysfunctional subcutaneous adipose tissue leading to ectopic fat deposition (undesirable lipid accumulation in the heart, liver, skeletal muscle, pancreas, etc.) [11].

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https://doi.org/10.1016/j.heliyon.2021.e06264
Received 17 June 2020; Received in revised form 8 September 2020; Accepted 9 February 2021

Notably, visceral adipose tissue is a component of total body fat, and abnormally high deposition of visceral adipose tissue is known as visceral obesity. This body composition phenotype is associated with cardiovascular disease and metabolic disease [12, 13]. Thus, the quantitative assessment of visceral obesity is important for evaluating the potential risk of developing cardiovascular disease and metabolic disease [14].

Visceral fat in the abdominal cavity can be assessed by many methods, such as bioelectrical impedance analysis (BIA), ultrasound, dual-energy X-ray absorptiometry (DXA), computed tomography scan (CT scan), and magnetic resonance imaging (MRI). BIA is a noninvasive method to assess the visceral fat in the abdominal cavity that is easily accessible and avoids exposure to radiation [1, 2, 15, 16]. BIA assesses visceral fat in the abdominal cavity and reports the visceral fat rating level. It is unknown how the visceral fat rating in the abdominal cavity assessed by a noninvasive procedure (BIA) correlates with the serum lipid profile and serum glucose from blood collection. Therefore, the purpose of this study is to investigate the correlation of visceral fat rating from noninvasive methods with serum lipid profile and serum blood sugar for assessing cardiovascular risk in obese adults.

2. Materials and methods

2.1. Study design, setting and sample size

This cross-sectional study was carried out at Walailak University Hospital, Nakhon Si Thammarat, Thailand, from 1 May 2019 to 31 August 2019. Ninety participants, forty-five men and forty-five women, between 18 and 60 years of age with a BMI $\geq$25 kg/m^2 voluntarily participated in this research after giving informed consent. The informed consent includes the details of the medical history, physical examination, anthropometric assessment, body composition measurement and blood collection for biochemical analysis. The exclusion criteria were patients who were taking lipid-lowering drugs within the previous 6 months, those taking hypoglycemic agents for diabetes mellitus and those who were pregnant. The sample size (N) was calculated by using the single proportion population formula:

$$N = Z^2\ p\ (1\text{-}p)\ /\ d^2$$

where p = prevalence of obesity from a previous study, d = precision, and Z = statistic for a level of confidence, which equals 1.96 for a 95% CI. The sample size was calculated based on the prevalence of obesity, 26% from a previous study [8], with a precision of 0.1 and a confidence level of 95%. From the calculation, at least 74 patients were required for our study. Therefore, the final sample size was 90 to account for a dropout rate of 20%. This study was approved by the Ethics Committee on Human Rights Related to Research Involving Human Subjects, Walailak University, Thailand (WUEC-18-036-01).

2.2. Demographic data collection

Demographic data, including age and underlying disease (e.g., dyslipidemia, hypertension, diabetes mellitus, hypothyroidism, liver disease, and renal failure), were obtained from the medical history and physical examination by physicians specializing in internal medicine. Medical history included information about use of medications (e.g., lipid-lowering drugs, hypoglycemic agents, steroids, thyroid hormones, diuretics, and contraceptive pills) and symptoms related to obesity, such as snoring, knee pain and acid reflux symptoms. The systolic blood pressure, diastolic blood pressure and pulse rate were measured by an automatic sphygmomanometer with an appropriate arm cuff at heart level after the patient had been sitting quietly for 5–15 min [17, 18]. Clinical signs of obesity complications, including the presence of acanthosis nigricans, arcus cornealis, xanthoma and osteoarthritis of the knee, were examined by physicians specializing in internal medicine.

2.3. Exercise data collection

The details of exercise were obtained by face to face review with regards to the frequency and duration. The definition of exercise is planned, structured, repetitive activity that improves the strengthening of the human body, such as running, riding a bicycle, swimming, tennis, walking for exercise, yoga and aerobic dance [19]. Question 1 was have you exercised in the past one month? If the answer was “Yes”, the participant was classified into the exercise group, and if the answer was “No”, the participant was classified into the non-exercise group. Question 2 was what is the frequency of your exercise per week? Question 3 was what is the duration (minutes) of your exercise per day?

2.4. Anthropometric assessment

The following anthropometric measurements were obtained: body weight, height, BMI, waist circumference and hip circumference, and waist-to-hip circumference ratio. Body weight and height were measured with patients wearing light clothing in a standing position and barefoot with an electronic digital scale and a stadiometer. Body height was recorded to the nearest 0.5 cm and body weight to the nearest 0.1 kg. BMI was calculated by body weight (kg) divided by height squared (m^2). Waist circumference (WC) was measured as the midpoint between the lower rib cage and iliac crest in the horizontal plane around the body, while in a standing position with a relaxed abdomen and the arms resting at the sides. The WC was measured to the nearest 0.1 cm at the end of a normal expiration [20, 21]. Hip circumference (HC) was measured at the widest point between the hips and buttocks. The waist-to-hip circumference ratio (WHR) was calculated by the WC divided by the HC [22]. An increased WC was defined as $\geq$ 90 cm in men and $\geq$80 cm in women. An increased WHR was defined as $\geq$ 0.9 in men and $\geq$0.85 in women [23].

2.5. Body composition measurement

Body composition measurement methods are continuously being perfected, with the most commonly used method being BIA [24]. BIA is a noninvasive, low-cost, and reliable method of body composition assessment [25]. The body composition parameters, including the visceral fat rating, percentage of body fat, fat mass (kg), fat-free mass (kg), muscle mass (kg), total body water (kg), percentage of total body water, bone mass (kg) and basal metabolic rate (kcal), are measured by a body composition analyzer (TANITA SC-330) in a standing position while barefoot after patients had taken off metal items, such as belts, earrings, and necklaces, as well as their outerwear [26, 27]. The Tanita body composition analyzer is a system to estimate the body composition based on the principle of bioelectrical impedance analysis. The BIA measures the body composition using a constant current source with a high frequency current (50 kHz, 90 μA). The 8 electrodes are positioned so that electric current is supplied from the electrodes on the tips of the toes of both feet, and the voltage is measured on the heels of both feet [28, 29]. The previous study showed that there is significant positive correlation between the visceral fat mass estimated by BIA and that measured by MRI [30, 31]. The Tanita 330 reports the visceral fat by using the visceral fat rating, and it cannot report the visceral fat area (VFA).The visceral fat rating is the level of visceral fat, while the visceral fat area is the area of adipose tissue measured at the umbilicus. Both the visceral fat and visceral fat area are representative of the cardiovascular risk in the human body [32, 33, 34]. The visceral fat can be measured by using BIA (Tanita 330), but the VFA was measured by a CT scan or MRI [32, 35]. For interpretation of the visceral fat rating level, we reviewed the previous studies [33, 34] and datasheets regarding visceral fat. The visceral fat rating level is the level of the fat that is in the internal abdominal cavity. The BIA measured the visceral fat rating in the range from 1 to 59 (low to high level). A higher level indicated more visceral fat. Previous studies showed that the level of visceral fat was associated with the risk

of cardiovascular diseases [33, 34]. The participants were classified into 3 groups using criteria for Asian populations: normal (visceral fat rating levels 1–9), high risk of cardiovascular disease (visceral fat rating levels 10–14) and very high risk of cardiovascular disease (visceral fat rating levels 15 and above) [33, 34].

2.6. Biochemical analysis

After fasting for 8–12 h, venous blood was collected by nurses and medical technicians with an aseptic technique for measuring the FBS, total cholesterol, high-density cholesterol (HDL-C), low-density cholesterol (LDL-C) and triglycerides. The serum was analyzed for the FBS and lipid levels with ABX Pentra 400 chemical analyzer equipment. The cutoff levels used in this study were as follows: an abnormal FBS level was ≥126 mg/dL; hypercholesterolemia, total cholesterol ≥200 mg/dL; low HDL-cholesterol, HDL-cholesterol < 40 mg/dL in men and <50 mg/dL in women; high LDL-cholesterol, LDL-cholesterol ≥ 100 mg/dL; and hypertriglyceridemia, serum triglycerides ≥150 mg/dL [36, 37].

2.7. Data analysis

Statistical analysis was performed using the R environment for statistical computing. Quantitative variables were described as the mean ± standard deviation for normally distributed data and the median and interquartile range for nonnormally distributed data. Categorical variables were expressed as percentages and frequencies. Differences between groups were analyzed by unpaired t-test to compare demographic, anthropometric, biochemical and BIA data. The correlation of the FBS and lipid profile with the body visceral fat rating was computed by Pearson's correlation analysis. After adjusting for confounding factors (sex, age and BMI) partial correlation coefficient analyses were performed separately for the female group and male group as well as the control factors age and BMI. In addition, the cutoff of visceral fat rating level to predict hypertriglyceridemia and predict low HDL-cholesterol in serum was analyzed by discriminant analysis.

3. Results

3.1. Demographic, anthropometric and biochemical data

A total of 90 participants, 45 females and 45 males, between 19 and 59 years of age were included in this study. The demographic, anthropometric and biochemical data are shown in Table 1. There was no statistically significant difference with regard to age between the female group (38.8 ± 10.95 years) and the male group (36.89 ± 11.45 years). The mean body weight and height of male subjects were significantly higher than those of female subjects. The mean BMI was not significantly different between the female (30.01 ± 4.72 kg/m^2) and male (30.64 ± 4.6 kg/m^2) groups. For the biochemical tests, the mean levels of the FBS, serum total triglycerides and LDL-cholesterol were significantly higher in the male group than in the female group. In addition, the mean serum HDL-cholesterol level was significantly lower in the male group than in the female group ($P = 0.009$).

3.2. Bioelectrical impedance analysis data

Table 2 shows the characteristics of BIA data between the female and male groups. The mean visceral fat rating, fat mass, muscle mass, total body water, bone mass and basal metabolic rate were significantly higher in the male group than in the female group. In addition, the mean body fat and fat mass were significantly lower in the male group than in the female group. Table 3 shows that the percentages of a normal visceral fat rating were 35.6% for levels 1–9, 37.8% for levels 10–14 and 26.7% for levels 15 and above. The percentage of BMI 25–29.9 kg/m^2 was 56.7%, and that of BMI ≥30 kg/m^2 was 43.3%. The percentage of the exercise group was 70%. The mean of exercise frequency was 3.1 ± 1.62 days/week, and the mean duration of exercise was 54.44 ± 36.78 min.

3.3. Correlation of the FBS and lipid profile with the visceral fat rating

Significant positive correlations were found between the serum triglycerides and visceral fat rating ($r = 0.287$, $P = 0.006$) and between the FBS and visceral fat rating ($r = 0.210$, $P = 0.047$). There was a negative correlation between the serum HDL-cholesterol and visceral fat rating ($r = -0.322$, $P = 0.002$) in Table 4.

3.4. Correlation of the FBS and lipid profile with the body visceral fat rating in the female and male groups (control factors: age and BMI)

There was a significant negative correlation between the serum HDL-cholesterol and the visceral fat rating in the female group ($r = -0.377$, $P = 0.013$) by using the partial correlation coefficient after controlling for age and BMI, as shown in Table 5.

3.5. The cutoff visceral fat rating level for predicting levels of serum triglycerides and HDL-cholesterol

A visceral fat rating level greater than 15 has a sensitivity of 40%, specificity of 81.8%, positive predictive value (PPV) of 58.3%, negative predictive value (NPV) of 68.2%, accuracy of 65.6%, positive likelihood ratio (LR+) of 2.20 and negative likelihood ratio (LR-) of 0.73 for predicting hypertriglyceridemia in Table 6. A visceral fat rating level greater

Table 1. Demographic, anthropometric and biochemical data.

Variables	Female (N = 45)	Male (N = 45)	*P*-value
	Mean ± SD	Mean ± SD	
Age (years)	38.8 ± 10.95	36.89 ± 11.45	0.421
Body weight (kg)	75.23 ± 13.39	88.92 ± 15.56	<0.001**
Height (cm)	158.2 ± 5.97	170.16 ± 5.85	<0.001**
BMI (kg/m^2)	30.01 ± 4.72	30.64 ± 4.6	0.519
Waist circumference (cm)	91.27 ± 10.33	99.69 ± 9.79	<0.001**
Hip circumference (cm)	105.04 ± 9.27	105.98 ± 9.59	0.640
Waist-to-hip circumference ratio	0.87 ± 0.05	0.94 ± 0.05	<0.001**
Fasting blood sugar (mg/dL)	98.51 ± 7.76	102.6 ± 9.81	0.031*
Serum total cholesterol (mg/dL)	219.53 ± 37.55	248.84 ± 44.16	0.001*
Serum triglycerides (mg/dL)	120.42 ± 49.88	155.16 ± 62.92	0.005*
Serum HDL-cholesterol (mg/dL)	54.33 ± 10.01	48.98 ± 8.98	0.009*
Serum LDL-cholesterol (mg/dL)	148.93 ± 36.54	174.22 ± 37.38	0.002*

*statistically significant at $P < 0.05$ **statistically significant at $P < 0.001$.

Table 2. Characteristics of bioelectrical impedance analysis (BIA).

Variables	Female (N = 45)	Male (N = 45)	*P*-value
	Mean ± SD	Mean ± SD	
Visceral fat rating	9 ± 2.08	14.62 ± 2.76	<0.001**
Body fat (%)	41.46 ± 5.5	28.31 ± 4.89	<0.001**
Fat mass (kg)	31.85 ± 10.7	25.78 ± 9.09	0.005*
Fat-free mass (kg)	43.41 ± 4.02	63.15 ± 7.25	<0.001**
Muscle mass (kg)	40.78 ± 3.68	59.89 ± 6.89	<0.001**
Total body water (%)	44.71 ± 1.65	52.25 ± 4.03	<0.001**
Bone mass (kg)	2.63 ± 0.35	3.26 ± 0.36	<0.001**
Basal metabolic rate (kcal)	1,363.84 ± 173.39	1,818.07 ± 262.56	<0.001**

*statistically significant at $P < 0.05$ **statistically significant at $P < 0.001$.

Table 3. Characteristics of the visceral fat rating, body mass index and exercise data.

Variables	Mean ± SD or n (%)	Median [Min, Max]
Visceral fat rating	11.81 ± 3.73	11 [6, 22]
1–9	32 (35.6%)	
10–14	34 (37.8%)	
≥15	24 (26.7%)	
BMI (kg/m^2)	30.33 ± 4.65	29.1 [24.8, 47.8]
Obesity 25–29.9	51 (56.7%)	
Morbid obesity ≥30	39 (43.3%)	
Exercise		
No	27 (30%)	
Yes	63 (70%)	
Exercise frequency (days/week)	3.1 ± 1.62	3 [1, 7]
Total exercise time per day (minutes)	54.44 ± 36.78	45 [15, 180]

Table 4. Correlation of the fasting blood sugar and lipid profile with the body visceral fat rating (N = 90).

Variables	Visceral fat rating	
	Correlation coefficient	*P*-value
Fasting blood sugar (mg/dL)	0.210*	0.047
Serum total cholesterol (mg/dL)	0.180	0.089
Serum triglycerides (mg/dL)	0.287**	0.006
Serum HDL-cholesterol (mg/dL)	-0.322**	0.002
Serum LDL-cholesterol (mg/dL)	0.201	0.058

*statistically significant at $P < 0.05$ **statistically significant at $P < 0.001$.

Table 5. Correlation of the FBS and lipid profile with the body visceral fat rating in the female and male groups (control factors: age and BMI).

Variables	Visceral fat rating Partial correlation coefficient (*P*-value)	
	Female (N = 45)	Male (N = 45)
Fasting blood sugar (mg/dL)	-0.253 ($P = 0.101$)	0.072 ($P = 0.648$)
Serum total cholesterol (mg/dL)	-0.256 ($P = 0.098$)	0.039 ($P = 0.805$)
Serum triglycerides (mg/dL)	0.011 ($P = 0.944$)	-0.099 ($P = 0.528$)
Serum HDL-cholesterol (mg/dL)	-0.377* ($P = 0.013$)	-0.174 ($P = 0.265$)
Serum LDL-cholesterol (mg/dL)	-0.053 ($P = 0.737$)	0.161 ($P = 0.301$)

*statistically significant at $P < 0.05$.

Table 6. Cutoff visceral fat rating level for predicting the level of hypertriglyceridemia (Serum total triglycerides ≥150 mg/dL).

Cutoff visceral fat rating (≥)	Sensitivity	Specificity	PPV	NPV	Accuracy	LR+	LR-
7	97.1%	3.6%	39.1%	66.7%	40.0%	1.01	0.79
8	91.4%	9.1%	39.0%	62.5%	41.1%	1.01	0.94
9	74.3%	21.8%	37.7%	57.1%	42.2%	0.95	1.18
10	65.7%	36.4%	39.7%	62.5%	47.8%	1.03	0.94
11	54.3%	45.5%	38.8%	61.0%	48.9%	1.00	1.01
12	51.4%	54.5%	41.9%	63.8%	53.3%	1.13	0.89
13	51.4%	65.5%	48.6%	67.9%	60.0%	1.49	0.74
14	45.7%	72.7%	51.6%	67.8%	62.2%	1.68	0.75
15	40.0%	81.8%	58.3%	68.2%	65.6%	2.20	0.73
16	31.4%	85.5%	57.9%	66.2%	64.4%	2.16	0.80
17	14.3%	90.9%	50.0%	62.5%	61.1%	1.57	0.94
18	8.6%	94.5%	50.0%	61.9%	61.1%	1.57	0.97
19	2.9%	94.5%	25.0%	60.5%	58.9%	0.52	1.03
20	2.9%	98.2%	50.0%	61.4%	61.1%	1.57	0.99

*** PPV: positive predictive value; NPV: negative predictive value; LR: likelihood ratio.

than 10 has a sensitivity of 33.3%, specificity of 63.6%, PPV of 25.0%, NPV of 72.4%, accuracy of 55.6%, LR+ of 0.95 and LR-of 1.05 for predicting low HDL-cholesterol in Table 7.

4. Discussion

This study demonstrated significant positive correlations between the serum triglycerides and visceral fat rating by BIA in age ≥40 years and BMI ≥30 kg/m^2 among obese adult participants, similar to a previous study that reported a positive correlation between the serum triglycerides and visceral fat from MRI among nondiabetic obese participants in Taiwan [38]. There was also a significant positive correlation between the FBS and visceral fat rating in age ≥40 years and BMI ≥25–29.9 kg/m^2. This finding was similar to a previous study in Japan demonstrating that abdominal adiposity was associated with insulin resistance in nondiabetic adults [39] and one in Korea reporting that the visceral fat mass measured using DXA is an indicator of diabetes or prediabetes in Korean adults [40]. In addition, our findings revealed a significant negative correlation between the HDL-cholesterol and the visceral fat rating in age <40 years and age ≥40 years. A previous study in a nondiabetic Chinese population demonstrated that HDL-cholesterol was correlated with the visceral fat area (VFA), as measured by computed tomography (CT) [35].

No statistically significant difference was found in the correlation between the total cholesterol and visceral fat rating when analyzing all participants, but there is significant positive correlation in the BMI 25–29.9 kg/m^2 group. A previous study in Japan also demonstrated no correlation between the total cholesterol and VFA measured by CT [41]. Another study conducted in a nondiabetic Chinese population demonstrated a positive correlation between the total cholesterol and VFA [35]. In addition, there was no correlation between LDL-cholesterol and the body visceral fat when analyzing all participants, but there was a significant positive correlation in the BMI 25–29.9 kg/m^2 group. Previous studies reported that the VFA was positively correlated with LDL-cholesterol in a nondiabetic Chinese population [35] and that the VFA measured by MRI was negatively correlated with LDL-cholesterol, indicating discordance between the cardiovascular risk and LDL-cholesterol [32].

In this study, a visceral fat rating level greater than 15 had a sensitivity of 40% and specificity of 81.8% for predicting hypertriglyceridemia. It is useful for confirmation but not appropriate in screening because of its low sensitivity. A visceral fat rating level greater than 10 had a sensitivity of 33.3% and specificity of 63.6% for predicting low HDL-cholesterol, and maybe the predicted HDL-cholesterol could be co-evaluated with another method.

Table 7. Cutoff visceral fat rating level for predicting the low HDL-cholesterol in serum (serum HDL-cholesterol < 40 mg/dL in males and <50 mg/dL in females).

Cutoff visceral fat rating (≥)	Sensitivity	Specificity	PPV	NPV	Accuracy	LR+	LR-
21	100.0%	1.5%	27.0%	100.0%	27.8%	1.02	0.00
20	100.0%	3.0%	27.3%	100.0%	28.9%	1.03	0.00
19	100.0%	6.1%	27.9%	100.0%	31.1%	1.06	0.00
18	100.0%	9.1%	28.6%	100.0%	33.3%	1.10	0.00
17	100.0%	15.2%	30.0%	100.0%	37.8%	1.18	0.00
16	91.7%	25.8%	31.0%	89.5%	43.3%	1.23	0.32
15	79.2%	28.8%	28.8%	79.2%	42.2%	1.11	0.72
14	79.2%	39.4%	32.2%	83.9%	50.0%	1.31	0.53
13	66.7%	43.9%	30.2%	78.4%	50.0%	1.19	0.76
12	62.5%	51.5%	31.9%	79.1%	54.4%	1.29	0.73
11	50.0%	56.1%	29.3%	75.5%	54.4%	1.14	0.89
10	33.3%	63.6%	25.0%	72.4%	55.6%	0.92	1.05
9	20.8%	75.8%	23.8%	72.5%	61.1%	0.86	1.05
8	8.3%	90.9%	25.0%	73.2%	68.9%	0.92	1.01
7	4.2%	97.0%	33.3%	73.6%	72.2%	1.38	0.99

*** PPV: positive predictive value; NPV: negative predictive value; LR: likelihood ratio.

This study demonstrated that the mean waist circumference, hip circumference, and waist-to-hip ratio in the male group were higher than those in the female group. These findings were similar to a previous study investigating diabetic patients [42]. The mean level of the FBS in the male group was higher than that in the female group, which is consistent with previous studies in Croatia [43], Japan [44] and Spain [45]. For lipid profiles, this study found that high mean levels of total cholesterol, triglycerides and LDL-cholesterol were observed in the male group compared with the female group. These findings were consistent with previous studies that reported high levels of these lipid profiles [43, 44, 46]. However, several studies showed no difference in LDL-cholesterol levels between the male and female groups [44, 46]. In addition, we found that the mean HDL-cholesterol in the male group was lower than that in the female group, which is similar to previous studies [43, 44, 46]. It was suggested that the possible causes of differences in the FBS and lipid profiles in both sexes may be associated with food intake, smoking and alcohol consumption, and sex hormones [45, 47].

In this study, the mean visceral fat rating measured by BIA was higher in the male group than in the female group. This finding was similar to a previous study in a Spanish population, which measured the visceral fat by DXA [45]. The mean percentages of body fat and fat mass in the male group were lower than those in the female group, which was consistent with previous studies in overweight/obese subjects [46] and healthy subjects [43]. In addition, the high levels of mean fat-free mass, muscle mass, and bone mass as well as basal metabolic rate in the male group were higher than those in the female group. These findings were consistent with previous studies [48, 49, 50, 51]. We suggested that the high levels of visceral fat, percentage of body fat, fat mass, fat-free mass, muscle mass, total body water, bone mass and basal metabolic rate in males may be associated with sex hormones, alcohol consumption, smoking, nutritional intake and physical activity [52]. Furthermore, in females, estrogen hormones may direct the expansion of fat through an increase in adiposity progenitor cells, affecting the percentage of fat in females more than in males [45, 53].

5. Conclusions

This study demonstrated a positive correlation between the serum triglycerides and visceral fat rating, a positive correlation between the FBS and visceral fat rating, and a negative correlation between the serum HDL-cholesterol and visceral fat measured by BIA in obese adults. Furthermore, these findings could be applied to perform a noninvasive procedure, BIA, to predict HDL-cholesterol but could be co-evaluated with another method.

Declarations

Author contribution statement

N. Sukkriang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

W. Chanprasertpinyo and A. Wattanapisi: Conceived and designed the experiments; Performed the experiments.

C. Punsawad: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

N. Thamrongrat and S. Sangpoom: Analyzed and interpreted the data; Wrote the paper.

Funding statement

This work was supported by Walailak University (Grant No. WU_IRG61_27) and the New Strategic Research (P2P) project (phase 2), Walailak University, Thailand.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors would like to acknowledge all volunteers in this research. The authors also thank the Director and staff of Walailak University Hospital for their support throughout the course of this study. Special thanks are also given to Mrs. Koleeyoh Samaeng, The Center for Scientific and Technological Equipment, Walailak University, for her assistance in body composition measurement.

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