Relationship of the Waist to Hip Ratio with Serum Lipids in Women

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Recent reports have shown that a high ratio of waist to hip circumference (WHR) may be associated with a high proportion of intra-abdominal fat. The metabolic complications of obesity, which are associated with a high WHR, may therefore relate specifically to the amount of intra-abdominal fat. The purpose of this study was to determine if WHR is associated with the concentration of serum lipids that may predispose individuals to a higher risk for metabolic complications. Serum lipids concentrations were determined in 45 female subjects, ranging from 31 to 40 years in age, and WHR ranging from 0.71 to 0.98. Positive correlations of WHR with the ratio of cholesterol to HDL-cholesterol ($r=0.641$, $p<0.001$) and with triglycerides ($r=0.479$, $p<0.001$), were found, while a negative correlation existed between WHR and HDL-cholesterol ($r=-0.600$, $p<0.001$). In order to investigate the relationship between the fat distribution in the body and the serum lipids, the subjects were divided into two groups according to their % Body fat; one group with a % Body fat more than 30 and the other with a % Body fat less than 30. The two groups differed significantly in WHR. In the group of obese women with high WHR (>0.87), the ratio of cholesterol to HDL-cholesterol and triglycerides were higher and HDL-cholesterol lower than in the normal group with low WHR (<0.80). There was a significant correlation between the HDL-cholesterol concentration and the WHR ($r=-0.869$, $p<0.001$) in the obese subjects with high WHR. The serum triglycerides ($r=0.688$, $p<0.001$) was also significantly correlated with the WHR. In conclusion, this study confirmed that for the obese women, the WHR at a higher risk of metabolic complications assessed by the measurement of serum HDL-cholesterol and triglycerides levels was found to be 0.95.

Key words: Waist to hip ratio, Intra-abdominal fat, Metabolic complications, Serum lipids

The importance of obesity as a risk factor in coronary heart disease (CHD) relates to the propensity of obese individuals to metabolic abnormalities such as glucose intolerance, hyperinsulinemia, and hyperlipemia (Hubert et al., 1983). The frequency of metabolic complications has recently been considered to be related with the distribution of body fat (Ashwell et al., 1985, Barakat et al., 1988, Despres et al., 1985, Fujioka et al., 1987, Kissebah et al., 1982, Lapidus et al., 1984, Larsson et al., 1984). Krotkiewski et al. (1983) reported that cardiovascular risk factors were more pronounced in subjects with a high ratio of waist to hip circumference (WHR).

Male type obesity is characterized by a high WHR where body fat is more abundant around the abdominal region (Ashwell et al., 1985). Fujioka et al. (1987) reported that the metabolic complications in plasma lipid levels associated with WHR may be more closely related to the abundance of intra-abdominal fat compared to subcutaneous fat. In 1965, Albrink and Meigs noted that upper body fat was more frequently associated with hypertriglyceridemia. Moreover, in obesity, low serum high-density lipoprotein cholesterol (HDL-ch) concentrations have been reported (Matter et al., 1980, Rosner and Halberg, 1978), which could be attributed

in part to the concomitant hyperlipemia (Nestel and Goldrick, 1976). Brakat et al. (1988) reported that high WHR (above 1.0) is associated with high levels of plasma triglycerides (TG) and low levels of HDL-ch. Therefore, body fat distribution is associated with numerous metabolic complications. However, little has been reported on the relationship between fat distribution and serum TG, HDL-ch in women. On the contrary, anthropometry cannot differentiate between the intra-abdominal and subcutaneous fat depots. Intra-abdominal fat may now be assessed by computed tomography. Since, it has been shown that WHR is associated with a high proportion of intra-abdominal fat, the present paper deals with the relationships between WHR and serum lipids in a sample of 45 women.

MATERIALS AND METHODS

The subjects for this study were 45 women volunteers referred to the Institute of Health Science of Kyushu University for assessment of health. The age of the women ranged from 31 to 40.

Body fat distribution was assessed by the measurement of the waist to hip circumference ratio (WHR). Waist circumference was measured to the nearest centimeter at the level of the umbilicus with the subject standing and breathing normally. Hip circumference was measured to the nearest centimeter at the level of the iliac crest. Body mass index (BMI) was calculated as weight/height². Skinfold thicknesses were measured with an Eiken caliper on the right side of the body at 5 regions: triceps, subscapular, suprailiac, abdomen and thigh. Percent body fat (% Body fat) was calculated by using the equation of Nagamine and Suzuki (1964) and Brožek et al. (1963). All anthropometric measurements were performed by the same trained observer.

Maximal oxygen uptake ($\dot{V}O_2\text{max}$) was estimated from a progressive submaximal test performed on a cycle ergometer, during which heart rate (HR) was recorded. Three consecutive twelve-minute work loads were used to progressively increase HR to a

target of 70% of HRmax at the end of the test. $\dot{V}O_2\text{max}$ was estimated by the extrapolation of $\dot{V}O_2$ -HR regression. Estimated HRmax was corrected for age.

Subjects came in the laboratory at 9 a.m., following an overnight fast, for blood sampling. Blood was collected in vacutainer tubes with anticoagulants and its serum was separated by centrifugation at $3000\times g$, 4°C, for 15 minutes. All biochemical analyses were performed at Creative Research Community, Inc. in Fukuoka.

Results were expressed as mean $\pm$ SD. Pearson product moment correlation coefficients were used to determine the association of WHR with serum lipids. This statistical method was also used to determine the association of WHR and other variables such as weight, % Body fat, BMI and $\dot{V}O_2\text{max}$. Moreover, subjects were divided into two groups: one group with a % Body fat less than 30% and the other with a % Body fat more than 30%. The significance of difference was determined by Student's t-test for unpaired data after an analysis of variance. Linear regression analyses were performed to quantify the effects of WHR and serum lipids.

RESULTS

The physical characteristics of the 45 women volunteers are presented in Table 1, together with correlations of WHR to various anthropometric variables. Although the mean WHR of the whole sample was 0.81, body weight varied largely from 43.88 to 66.67kg. A large range was seen also in degree of obesity (14.6–45.9% Body fat). Similarly, the ranges of BMI (17.6–28.7) and $\dot{V}O_2\text{max}$ (20.7–53.9 ml/kg/min) were extremely large. WHR was significantly and positively associated with body weight, five circumferences, five skinfolds, % Body fat and BMI, but was negatively correlated with $\dot{V}O_2\text{max}$.

The concentrations of serum lipids and glucose of the whole sample are shown in Table 2. The concen-

Table 1 The physical characteristics of the 45 women subjects.

	Mean±S.D	Range	r
WHR	0.81±0.057	0.71–0.98	
Age, yrs	35.5±2.52	31–40	0.181
Height, cm	157.1±4.64	146.8–167.3	–0.068
Body weight, kg	52.39±5.951	43.88–66.67	0.661***
Chest girth, cm	81.6±6.26	72.3–103.0	0.787***
Upper arm girth, cm	23.8±1.82	20.6–28.0	0.656***
Thigh girth, cm	48.6±3.14	42.1–58.1	0.489***
Abdominal girth, cm	70.5±7.08	59.5–89.2	0.916***
Hip girth, cm	86.5±3.85	78.5–96.3	0.494***
Skinfolds, mm			
Triceps	17.4±4.97	7.5–31.5	0.645***
Subscapular	20.2±8.16	8.0–47.0	0.712***
Suprailiac	20.1±7.37	6.0–37.0	0.741***
Abdomen	22.7±7.94	8.0–40.5	0.722***
Thigh	23.4±5.67	14.0–39.0	0.501***
% Body fat	25.5±6.81	14.6–45.9	0.756***
BMI	21.3±2.56	17.6–28.7	0.681***
$\dot{V}O_2$ max, ml/kg/min	35.1±7.07	20.7–53.9	–0.307*
SBP, mmHg	115±10.6	96–139	0.101
DBP, mmHg	69±10.7	50–100	0.212

r; raw correlation

* $p < 0.05$, *** $p < 0.001$ **Table 2** Mean, standard deviation, and range of serum lipids and glucose.

	Mean±SD	Range	r
WHR	0.81±0.057	0.71–0.98	
Cholesterol, mg/dl	177±31.7	114–251	0.100
HDL-ch., mg/dl	66±15.4	32–91	–0.600***
Ch. /HDL-ch.	2.86±0.910	1.56–6.22	0.641***
Triglycerides, mg/dl	75±50.4	19–297	0.479***
LDL-ch., mg/dl	97±27.9	29–155	0.274
Glucose, mg/dl	87±8.3	72–109	0.109

*** $p < 0.001$

LDL-cholesterol concentrations were estimated using the Friedewald formula.

trations of serum lipids and glucose varied largely although the mean values were within the normal range. The significant, positive correlations between WHR and the ratio of cholesterol/HDL-cholesterol and triglycerides were observed, but the HDL-cholesterol was correlated negatively with WHR.

In order to investigate the relationship between the fat distribution (WHR) in the body and the serum lipids, the subjects were divided into two

groups according to their percent body fat (% Body fat); one group with a % Body fat greater than 30 (diagnosed as an obese group) and the other with a % Body fat less than 30 (diagnosed as a normal group). The physical characteristics and serum lipids values of the 15 matched pairs are presented in Tables 3 and 4. The two groups were well matched in $\dot{V}O_2$ max but differed significantly in WHR and all other physical variables. Significant differences were also found in HDL-cholesterol, the

Table 3 The physical characteristics of the low and high % Body fat groups.

	Low % Body fat n=33		High % Body fat n=12		t
	Mean±SD	r	Mean±SD	r	
WHR	0.80±0.04		0.87±0.06		p<0.01
Body weight, kg	50.05±4.158	0.427***	58.82±5.460	0.572*	p<0.01
Chest girth, cm	79.2±4.02	0.607***	88.4±6.43	0.770**	p<0.01
Upper arm girth, cm	22.9±1.27	0.370*	26.0±0.99	0.741**	p<0.01
Thigh girth, cm	47.6±2.61	0.352*	51.2±3.08	0.234	p<0.01
Abdominal girth, cm	67.8±4.64	0.846***	78.1±7.27	0.932***	p<0.01
Hip girth, cm	85.1±3.06	0.252	90.4±3.16	0.267	p<0.01
Skinfolds, mm					
Triceps	15.4±3.79	0.612***	22.8±3.66	0.224	p<0.01
Subscapular	16.6±4.80	0.500**	30.2±7.31	0.622*	p<0.01
Suprailiac	17.6±6.17	0.627***	26.8±6.21	0.687**	p<0.01
Abdomen	19.7±6.38	0.573***	31.0±5.64	0.689**	p<0.01
Thigh	21.7±5.00	0.324	28.2±4.69	0.323	p<0.01
% Body fat	22.3±4.13	0.638***	34.2±4.69	0.676**	p<0.001
BMI	20.1±1.34	0.324	24.5±2.40	0.674**	p<0.001
VO ₂ max, ml/kg/min	35.9±6.38	-0.258	32.9±8.58	-0.224	NS

Low ; 30>% Body fat, High ; 30<% Body fat, * p<0.05, ** p<0.01, *** p<0.001

t ; Student's t-test

Table 4 Comparisons of serum lipid values of normal and obese subjects, and correlations between WHR and serum lipids in each group.

	Low % Body fat n=33		High % Body fat n=12		t
	Mean±S.D	r	Mean±S.D	r	
WHR	0.80±0.04		0.87±0.06		p<0.01
Cholesterol, mg/dl	175±28.9	-0.163	184±39.1	0.301	NS
HDL-ch., mg/dl	69±13.9	-0.551***	54±13.7	-0.869***	p<0.01
Ch./HDL-ch.	2.63±0.674	0.378*	3.50±1.182	0.707**	p<0.01
Triglycerides, mg/dl	63±46.7	0.158	110±45.2	0.688**	p<0.01
LDL-ch. mg/dl	94±26.0	0.059	106±32.1	0.418	NS
Glucose, mg/dl	86±7.9	-0.099	89±9.3	0.217	NS

* p<0.05, ** p<0.01, ***p<0.001

ratio of cholesterol/HDL-cholesterol, and triglycerides.

Fig. 1 shows the significant relationship between the WHR and the serum HDL-cholesterol ($r = -0.869$, $p < 0.001$) and triglycerides concentrations ($r = 0.688$, $p < 0.001$) of the obese subjects. The WHR at higher risk of metabolic complications was found to be 0.95, since the abnormal values of HDL-cholesterol and triglycerides were 40mg/dl and 150mg/dl, respectively.

Table 5 presents the physical and metabolic fea-

tures of the obese subjects with increasing WHR (> 0.95). Of the serum lipids, HDL-cholesterol was lower and the ratio of cholesterol to HDL-cholesterol higher among the individuals with high WHR. Total cholesterol, triglycerides and LDL-cholesterol levels of the subjects with high WHR were higher than those of whole sample.

DISCUSSION

It has been established that obesity is an independent risk factor for cardiovascular disease (Hubert et

Fig. 1 Correlation of HDL-cholesterol and triglycerides of the WHR.

al., 1983). Obesity is, however, associated with several cardiovascular risk factors; elevated cholesterol (Barakat et al., 1988) and triglycerides (Barakat et al., 1988, Bjorntorp et al., 1971), reduced HDL-cholesterol levels (Barakat et al., 1988), hypertension (Staessen et al., 1988), and noninsulin-dependent diabetes (Leonhardt et al. 1978). Furthermore, metabolic complications in obesity is frequently associated with abdominal fat (with a high WHR) (Barakat et al., 1988, Fujioka et al., 1987, Kissebah et al., 1982). Although abdominal fat is known to be composed of subcutaneous fat and intra-abdominal fat, the anthropometry cannot differentiate between subcutaneous fat and intra-abdominal fat depots. Ashwell et al. (1985) recently revealed a close and significant correlation between the intra-abdominal fat to the WHR, using CT scanning at an umbilical level. Therefore, the main objective of this study was to determine whether WHR correlates with the concentrations of serum

Table 5 Physical and metabolic features of the obese subjects with increase in WHR.

	High % Body fat (>30%)
WHR	>0.95
Body weight, kg	62.77
Chest girth, cm	94.7
Upper arm girth, cm	26.9
Abdominal girth, cm	86.6
Skinfolds, mm	
Subscapular	35.9
Suprailiac	32.2
Abdomen	35.9
% Body fat	38.2
BMI	26.5
Cholesterol, mg/dl	199
HDL-ch., mg/dl	38
Ch./HDL-ch.	4.55
Triglycerides, mg/dl	149
LDL-ch.	123
Glucose, mg/dl	92

lipids which have been known to be associated with metabolic complications risk. In the 45 women, WHR was positively correlated with body weight, circumferences, skinfolds, % Body fat and BMI, but was negatively correlated with $\dot{V}O_2\text{max}$. Additionally, we found that WHR was positively correlated with the concentrations of triglycerides, and the ratio of cholesterol/HDL-cholesterol, but was negatively correlated with HDL-cholesterol. These findings are in agreement with the findings of other investigators.

To minimize the influence of body fat content on serum lipid concentrations, the subjects were divided into two groups according to their % Body fat. The two groups were similar in $\dot{V}O_2\text{max}$, but differed not only in WHR but also in many other physical variables. Of the serum lipids, HDL-cholesterol was lower and the ratio of cholesterol to HDL-cholesterol higher, in the obese subjects with high WHR. Additionally, triglycerides concentrations of the obese subjects with high WHR were higher than those of the normal subjects with low WHR. The intra-abdominal fat, which may be partly included in the WHR measurement, is of particu-

lar importance for the metabolic complications because of their unique position and relationship to the portal circulation (Krotkiewski et al., 1983). Consequently, the liver is directly exposed to the lipolytic products of the intra-abdominal adipocytes. It is known that the high free fatty acids released from the large intra-abdominal fat cells into the circulation could produce hypertriglyceridemia (Bjorntorp et al., 1971) and alter glucose metabolism in other tissues, thus leading to insulin resistance (Randle et al., 1963). Although hypertriglyceridemia is well related to obesity, the mechanism by which obesity affects HDL-cholesterol level is not fully understood. However, reports from the Gothenburg study (Lapidus et al., 1984, Larsson et al. 1984) have recently indicated that the WHR is the anthropometric indicator best associated with the incidence of CHD. This report is therefore consistent with the concept that the regional distribution of the fat is important. Thus, the ratio of waist to hip circumferences is a good predictor of the obesity complications.

In conclusion, this study confirmed that the WHR at higher risk of metabolic complications assessed by the measurement of serum HDL-cholesterol and triglycerides levels was found to be 0.95, for the obese women.

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