Association Between Serum Leptin and Adiponectin Levels with Risk of Insulin Resistance and Impaired Glucose Tolerance in Non-diabetic Women

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Obesity is a well known risk factor for insulin resistance and type 2 diabetes. Recently discovered adipocyte-derived proteins (leptin and adiponectin) might contribute to the pathologic mechanism linking obesity and insulin resistance. A total of 190 non-diabetic women were recruited from the Obesity Clinic of Kaohsiung Municipal Hsiao-Kang Hospital, Taiwan, between February 2003 and February 2004. All participants completed a simple questionnaire. Blood pressure and body mass index were measured; blood samples for fasting glucose, total cholesterol, high-density lipoprotein cholesterol, triglyceride, leptin, adiponectin, and fasting insulin level were collected after an overnight fast. Two-hour glucose level after a 75-g glucose tolerance test was determined. Homeostasis model assessment of insulin resistance (HOMA-IR) was calculated as the index of insulin resistance. Multivariate linear regression analyses were used to analyze the relationship between adipocytokines and insulin resistance after adjusting for possible confounding factors. Leptin and adiponectin were found to be independently associated with HOMA-IR and fasting insulin concentration, but in divergent directions, after adjusting for potential confounding factors. Adiponectin, but not leptin, was associated with impaired glucose tolerance after adjusting for potential confounding factors. The results suggest that leptin and adiponectin may be involved in the pathophysiologic link between obesity and insulin resistance independently. Low levels of adiponectin may increase the risks of developing impaired glucose metabolism and type 2 diabetes.

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Obesity is a well-known risk factor for insulin resistance, which in turn increases the risk of developing type 2 diabetes [1]; however, the pathological mechanism that links obesity and insulin resistance is not fully understood. Recent studies suggested that adipocytokines, products of adipocytes, play a role in this

association. Leptin and adiponectin, two of the most abundant adipocyte products, are thought to link obesity, insulin resistance, and related disorders [2,3].

Leptin, an obese gene product, is a 16-kDa protein and is predominantly expressed in adipose tissue [4]. Leptin regulates body weight by modulating appetite and energy expenditure by acting on the hypothalamus and inhibiting the release of neuropeptide Y in mice and humans [5]. Rising levels of leptin will cause a signal to be sent to the brain, which then attempts to protect the subject from obesity by decreasing appetite and increasing energy expenditure. Nevertheless, most obese humans have elevated concentrations of leptin [6], suggesting that these people develop leptin resistance. Meanwhile, studies have also shown that insulin resistance is particularly prevalent in obese humans and have reported an independent association between insulin resistance and elevated plasma leptin levels [7,8]. The coinciding plasma leptin levels, plasma insulin levels and body fat suggest that leptin might be involved in the link between obesity and β-cell hypersecretion.

Adiponectin is a relatively abundant plasma protein of approximately 30 kDa in size specifically secreted from adipose tissue [9]. Although the expression of adiponectin mRNA occurs exclusively in adipose tissue, interestingly, the adiponectin concentration is decreased in obese subjects [10]. Previous reports have demonstrated that diabetic subjects have lower levels of plasma adiponectin than non-diabetic subjects, independent of body mass index (BMI) [11], indicating an association between lower adiponectin levels and type 2 diabetes.

Although it appears that leptin and adiponectin may contribute to the development of insulin resistance and type 2 diabetes in obese subjects, the association between adiponectin and insulin resistance and type 2 diabetes may be modulated by leptin, or *vice versa*. Insulin resistance is an important risk factor for type 2 diabetes. Therefore, we examined the associations between leptin and adiponectin with insulin resistance in non-diabetic women.

Methods and Subjects

Study population

A total of 190 women were recruited from the Obesity Clinic at Kaohsiung Municipal Hsiao-Kang Hospital, Taiwan, between February 2005 and February 2006. Eligible subjects were those who did not have diabetes or were not taking medications that affect glucose, blood pressure, or lipid metabolism. Subjects whose body weight increased or decreased by more than 5 kg in 6 months before entering the study were also excluded. All participants completed a simple questionnaire on their medication history and lifestyle characteristics, including cigarette smoking according to the categories "never", "former" (quit smoking at least 1 year ago) and "current smoker" (smoke more than one cigarette/day for at least 1 year) and exercise according to the categories "not regular" (less than 150 minutes per week at less than a moderate intensity of exercise) and "regular exerciser" (at least 150 minutes per week at a moderate or greater intensity of exercise). Written informed consent was obtained from all study subjects, and the study was approved by the Human Experiment and Ethics Committee of Kaohsiung Municipal Hsiao-Kang Hospital.

Anthropometry and blood pressure assessment

Height and body weight were measured without shoes and with the study subjects wearing light clothes. Height was measured to the nearest 0.1 cm, and weight was measured to the nearest 0.1 kg. BMI was calculated as weight/height^2 (kg/m^2). Subjects were classified into: (1) normal/overweight; (2) obese; and (3) severely obese, based on a definition of obesity for the population in Taiwan, with BMI cut-off values of 27 and 30 kg/m^2, respectively. Waist circumference was measured to the nearest 0.1 cm at the level between the midpoint of the lowest rib and iliac crest parallel to the floor in a standing position, while the hip circumference was measured to the nearest 0.1 cm at maximum extension of the buttocks. The waist-to-hip ratio was calculated as an index of central obesity. Percent body fat was measured by bioelectrical impedance analysis (BIA) using the Tanita TBF-410 Body Fat Analyzer (Tanita Corp., Tokyo, Japan). The instrument has been previously validated against dual-energy X-ray absorptiometry [12]. Subjects were requested not to eat or drink anything for at least 2 hours and to refrain from strenuous exercise or consuming alcohol for 12 hours before BIA measurement to avoid perturbation of hydration status. Blood pressure was measured using a sphygmomanometer; two readings were taken at 10-minute intervals after subjects had

been seated for at least 10 minutes. The two readings were averaged.

Adipocytokines, insulin resistance and metabolic profiles

Fasting glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, insulin, leptin, and adiponectin were measured using blood samples obtained after the participants had fasted overnight. Cholesterol, HDL cholesterol, and triglyceride concentrations were analyzed by enzymatic colorimetric methods and the fasting glucose level was measured by the glucose oxidase method. At 2 hours after a 75-g oral glucose tolerance test, blood was drawn and the glucose level was measured by a glucose dehydrogenase method. The 2-hour glucose level was used as an index of abnormal glucose metabolism. Using criteria established by the World Health Organization in 1999 [13], we classified our subjects into those with normal glucose levels, impaired fasting glucose, impaired glucose tolerance (IGT), or type 2 diabetes. Subjects with type 2 diabetes were excluded from the study. Plasma leptin, adiponectin and insulin levels were measured using a radioimmunoassay from Linco Research, Inc. (St Charles, MO, USA); intra- and interassay coefficients of variation were 3.9% and 4.6% for leptin, 6.2% and 6.9% for adiponectin, and 2.2% and 3.8% for insulin, respectively. Insulin resistance was estimated from the homeostasis model assessment of insulin resistance (HOMA-IR) originally described by Matthews et al [14] as follows:

HOMA-IR = [fasting insulin concentration (μU/mL) × fasting glucose concentration (mmol/L)]/22.5.

Statistical analysis

Descriptive data are expressed as means and standard deviations or frequencies and percentages. Pearson correlation coefficients were used to determine the associations between leptin, adiponectin and continuous variables. Linear trends of leptin and adiponectin levels and metabolic parameters was tested across the three obesity subgroups using the Mantel-Haenszel test with adjustment for age, exercise and smoking status. Multiple regression analysis was used to examine the association between parameters of insulin resistance (HOMA-IR, fasting insulin levels or 2-hour glucose levels) and adipocytokines (leptin and adiponectin) after adjusting for age, smoking status and exercise. Multiple logistic regression analysis was used to explore the association between IGT (2-hour glucose level > 140 mg/dL) and adipocytokines after controlling for potential confounding factors such as age, BMI, fasting glucose level, fasting insulin level, triglyceride, HDL cholesterol and blood pressure. All statistical operations were performed using Stata SE software version 9.0 (StataCorp LP, College Station, TX, USA). A p value of less than 0.05 was considered significant.

RESULTS

Descriptive data are shown in Table 1. The subjects with BMI $\geq 30\,kg/m^2$ were, on average, slightly younger than those in the other two groups (Table 1). Regular exercisers were more prevalent in the relatively lean group (BMI $< 27\,kg/m^2$). The prevalence of current smokers was less than 10% in all three groups. Mean values for fasting glucose, 2-hour glucose, triglycerides, insulin, HOMA-IR, leptin, and systolic and diastolic blood pressure increased with increasing BMI, after adjusting for age, exercise and smoking status. In contrast, levels of HDL cholesterol and adiponectin increased with decreasing BMI. Table 2 shows that plasma leptin was positively correlated with measures of obesity, fasting insulin and HOMA-IR, but was not correlated with fasting glucose, 2-hour glucose, triglycerides, HDL cholesterol or blood pressure. Adiponectin was negatively correlated with measures of obesity, fasting insulin, HOMA-IR, 2-hour glucose levels and triglycerides, and positively correlated with HDL cholesterol. Leptin and adiponectin levels were inversely and significantly correlated.

The associations between leptin, adiponectin, insulin resistance and hyperinsulinemia are shown in Table 3. The multiple linear regression analyses revealed that serum leptin levels were positively and significantly associated with HOMA-IR ($R^2 = 31.6\%$) and insulin level ($R^2 = 39.2\%$), but not 2-hour glucose after controlling for the effects of adiponectin, age, smoking status, exercise and BMI. Serum adiponectin levels were negatively and significantly associated with HOMA-IR, insulin level and 2-hour glucose, after controlling for the effects of leptin, age, smoking status, exercise and BMI.

We then dichotomized the subjects for the presence of IGT and found that adiponectin level, but not leptin level, was significantly associated with IGT after

Table 1. Participant characteristics and metabolic measures according to degree of obesity

	BMI < 27 (n = 70)	27 ≤ BMI < 30 (n = 58)	BMI ≥ 30 (n = 62)	
Age (yr)	42.9 ± 12.0	41.6 ± 9.4	36.5 ± 12.0	
Current smoker (%)	5 (7.1)	2 (3.5)	5 (8.1)	
Exercise (%)	32 (45.7)	28 (48.3)	25 (40.3)	
BMI (kg/m^2)	24.4 ± 1.8	28.4 ± 0.8	34.6 ± 4.2	
Waist-to-hip ratio	0.82 ± 0.06	0.85 ± 0.06	0.85 ± 0.05	
Waist circumference	82.0 ± 6.4	90.1 ± 6.4	99.4 ± 9.7	
% body fat	34.0 ± 4.5	40.0 ± 4.3	47.6 ± 7.5	
				p for trend*
Fasting glucose (mg/dL)	91.7 ± 8.3	94.6 ± 10.7	93.8 ± 12.0	0.04
2-hr glucose (mg/dL)	105.3 ± 27.3	110.1 ± 29.4	116.6 ± 31.1	0.004
TG (mg/dL)	105.1 ± 55.5	134.0 ± 64.3	138.0 ± 62.3	0.001
HDL cholesterol (mg/dL)	59.5 ± 16.2	53.4 ± 13.4	50.2 ± 9.0	< 0.0001
Fasting insulin (μIU/mL)	6.2 ± 5.0	9.2 ± 6.6	15.7 ± 9.0	< 0.0001
HOMA-IR (μU·mol^{-1}·L^{-3})	1.5 ± 1.4	2.2 ± 1.7	3.6 ± 2.1	< 0.0001
Leptin (μg/dL)	15.5 ± 8.0	19.6 ± 6.6	30.6 ± 12.6	< 0.0001
Adiponectin (μg/dL)	10.5 ± 5.3	7.5 ± 3.8	7.0 ± 3.3	< 0.0001
SBP (mmHg)	123.1 ± 13.1	131.1 ± 15.4	131.8 ± 14.0	< 0.0001
DBP (mmHg)	79.8 ± 9.5	84.5 ± 9.8	85.0 ± 9.4	0.0001

*Trend analysis was adjusted for age, exercise and smoking status. BMI = body mass index; TG = triglycerides; HDL = high-density lipoprotein; HOMA-IR = homeostasis model assessment of insulin resistance; SBP = systolic blood pressure; DBP = diastolic blood pressure.

controlling for covariates including age, BMI, exercise, smoking status, fasting glucose, HDL cholesterol, triglycerides, fasting insulin, systolic blood pressure and diastolic blood pressure (Table 4). Every 1 ng/dL increase in adiponectin level was associated with a 0.22-fold decreased risk of having IGT. When we categorized subjects according to adiponectin levels into tertiles, we found that subjects in the highest adiponectin tertile (> 9.1 μg/dL) had significantly decreased risk of having IGT (odds ratio, 0.03; 95% confidence interval, 0.004–0.30; p = 0.002) compared with those in the lowest tertile, after controlling for other covariates including age, BMI, exercise, smoking status, fasting glucose, HDL cholesterol, triglycerides, fasting insulin, systolic blood pressure and diastolic blood pressure (Table 4). In contrast, we found no significant effect of leptin level, by tertiles, on the risk of IGT.

Discussion

The aim of our study was to examine the associations between leptin, adiponectin and insulin resistance after controlling for obesity and other covariates, because leptin, adiponectin and insulin resistance are all highly correlated with obesity. We found that higher BMI levels were associated with higher concentrations of leptin, fasting insulin, HOMA and lower concentrations of adiponectin. The physiologic function of leptin is to provide a signal to the brain to decrease appetite, increase fuel consumption and control stores of body fat in rodents and humans [6,15]. However, instead of leptin deficiency, the leptin concentration was positively associated with adiposity in our study. Moreover, other studies have revealed that the elevated circulating plasma leptin does not suppress appetite or prevent fat deposition in obese humans [16], which suggests that hyperleptinemia rather than leptin deficiency is a common feature of human obesity, because the concentrations of leptin in plasma may reflect the degree of body adiposity in most human beings. In contrast to leptin, adiponectin was decreased in the obese subjects in our study and in other studies [10,17], even though adiponectin is mainly synthesized in adipose tissue. Taken together, obese subjects tend to have high levels of leptin, low levels of adiponectin and hyperinsulinemia.

Obesity, particularly visceral obesity, is an important risk factor for insulin resistance. The significant positive association between BMI and insulin resistance (HOMA-IR and fasting insulin level) was also demonstrated in our study. Whether the association

Table 2. Pearson correlation coefficients between leptin, adiponectin, obesity (including BMI, waist-to-hip ratio and percent body fat), and metabolic profiles

	BMI	WHR	% Fat	Fasting glucose	2-hr glucose	TG	HDL-C	SBP	DBP	Insulin	HOMA-IR	Leptin	Adiponectin
Leptin	0.72*	0.12	0.69*	–0.09	0.06	0.13	–0.08	0.12	0.1	0.51*	0.45*	–	–0.16‡
Adiponectin	–0.28*	–0.19†	–0.30*	–0.11	–0.29*	–0.28*	0.43*	–0.08	–0.14	–0.32*	–0.30*	–0.16‡	–

*$p < 0.001$; †$p < 0.01$; ‡$p < 0.05$. BMI = body mass index; WHR = waist-to-hip ratio; TG = triglycerides; HDL-C = high-density lipoprotein cholesterol; SBP = systolic blood pressure; DBP = diastolic blood pressure; HOMA-IR = homeostasis model assessment of insulin resistance.

between obesity and insulin resistance is causal or due to an underlying association with confounding variables remains to be clarified. Therefore, our analyses were adjusted for measures of obesity and potential confounding factors to examine the relationship between leptin, adiponectin and insulin resistance. The results revealed that high leptin levels and low adiponectin levels were independently associated with hyperinsulinemia and insulin resistance, suggesting that high leptin levels and low adiponectin levels are associated with hyperinsulinemia and insulin resistance independently of obesity, and may play a role in the development of insulin resistance. Boden et al [18] observed that prolonged infusion of insulin dependently increases serum leptin concentration during euglycemic-hyperinsulinemic clamps in non-obese young men. Some studies also showed that insulin can stimulate leptin secretion due to increased triglyceride storage in fat cells [19,20], while leptin may directly suppress insulin secretion from pancreatic islets isolated from *ob/ob* mice and humans [21,22]. However, insulin secretion did not affect leptin synthesis in hyperleptinemic insulin-resistant individuals independently of the level of obesity [7]. Taken together, these findings suggest that there is a feedback pathway between leptin and insulin secretion, but the development of "insulin insensitivity" or "leptin insensitivity" could adversely affect the association between leptin and insulin, and stimulate the progression to hyperinsulinemia and impaired glucose metabolism.

The relationship between adiponectin and insulin resistance/hyperinsulinemia in our study can be explained by some experimental studies. Expression of the adiponectin receptor was detected in rat and human β-cells [23] and the expression of adiponectin can be stimulated by insulin [17], which suggests that adiponectin may modulate β-cell function. The administration of adiponectin to normal, obese and diabetic rodents decreased gluconeogenesis in the liver and increased fatty acid oxidation in muscle [24] and thus regulates insulin sensitivity and energy homeostasis. However, the effect of adiponectin on insulin secretion is controversial. Staiger et al [25] demonstrated that adiponectin does not affect insulin secretory function of healthy human islets *in vitro*. Winzell et al [26] reported a dual effect of adiponectin to modify insulin secretion in insulin-resistant mice because adiponectin inhibited insulin secretion at low glucose

Table 3. Multiple regression analyses of adipocytokines and insulin resistance*

	HOMA-IR			Insulin			2-hr glucose		
	B	SE	*p*	*B*	SE	*p*	*B*	SE	*p*
BMI	0.10	0.04	0.004	0.44	0.14	0.002	0.31	0.60	NS
Leptin	0.03	0.02	0.036	0.16	0.06	0.009	0.16	0.26	NS
Adiponectin	–0.09	0.03	0.001	–0.36	0.11	0.001	–1.87	0.46	< 0.0001
Model R^2		31.6			39.2			15.3	

*Each model was adjusted for age, cigarette smoking and exercise. HOMA-IR = homeostasis model assessment of insulin resistance; BMI = body mass index; SE = standard error.

Table 4. Multiple regression analysis for leptin, adiponectin and the presence of impaired glucose tolerance

	No. of subjects with IGT Yes/No	Model 1* OR (95% CI)	Model 2† OR (95% CI)
Leptin			
Continuous		1.01 (0.95–1.108)	
Tertiles (μg/dL)			
< 15.7	10/53		Reference
15.7–23.7	10/52		1.04 (0.32–3.40)
> 23.7	11/54		2.27 (0.48–10.65)
Adiponectin			
Continuous		0.78 (0.67–0.92)	
Tertiles (μg/dL)			
< 5.9	17/46		Reference
5.9–9.1	13/50		0.67 (0.27–1.69)
> 9.1	1/63		0.03 (0.004–0.30)

*Adjusted for age, body mass index, exercise, smoking status, fasting glucose, high-density lipoprotein cholesterol, triglycerides, fasting insulin, systolic and diastolic blood pressure, and leptin and adiponectin were analyzed as continuous variables in the model; †adjusted for age, body mass index, exercise, smoking status, fasting glucose, high-density lipoprotein cholesterol, triglycerides, fasting insulin, systolic and diastolic blood pressure, and leptin and adiponectin were analyzed as categorical variables in the model. IGT = impaired glucose tolerance; OR = odds ratio; CI = confidence interval.

(2.8 mM) but augmented insulin secretion at high glucose (16.7 mM) concentration. In contrast, adiponectin did not have an acute effect on insulin secretion in islets from normal mice. Therefore, we believe that adiponectin modulates insulin secretion but involves a complicated mechanism. Recent studies have found that the adiponectin level is decreased in patients with type 2 diabetes or coronary heart disease [28], and is associated with anti-inflammation [27,28]. One randomized interventional trial of weight reduction revealed that body weight reductions were associated with increased adiponectin levels and decreased levels of inflammatory factors such as C-reactive protein, tumor necrosis factor (TNF)-α, and interleukin (IL)-6 [29], indicating that adiponectin might protect against inflammation and atherosclerosis. However, it has also been reported that inflammatory mediators, such as TNF-α and IL-6, which are increased in obese and insulin resistant individuals, can suppress the transcription of adiponectin in adipocyte cell lines [30,31], which explains, at least in part, the decreased level of adiponectin in obese subjects.

Leptin, adiponectin and IGT

We found that the level of adiponectin, but not leptin, was associated with 2-hour glucose level after controlling for BMI, age, cigarette smoking and exercise status. We then classified the study subjects into those with or without IGT, and found that high adiponectin levels were independently associated with decreased risk of developing IGT (odds ratio, 0.78) after controlling for possible confounding variables including BMI, age, fasting glucose level, HDL cholesterol, triglycerides, fasting insulin concentration, systolic and

diastolic blood pressure, cigarette smoking and exercise. Meanwhile, subjects in the highest adiponectin tertile had the lowest risk of having IGT. IGT has been used as a marker for insulin resistance [32], denoting a pre-diabetic state in which subjects are at increased risk of progressing to diabetes [33], premature mortality and cardiovascular disease [34]. These findings suggest that low levels of adiponectin may be involved in the pathogenesis of abnormal glucose metabolism. A prospective cohort study by Snijder et al [35] has reported that low levels of adiponectin are independently associated with a higher risk of IGT and type 2 diabetes in elderly Caucasian women. Another study by Tso et al [36] revealed that polymorphisms of *ADIPOQ*, the gene encoding adiponectin, was associated with glycemic status in southern Chinese people, suggesting a biomolecular mechanism for adiponectin and abnormal glucose metabolism. However, we did not find an association between leptin and 2-hour glucose level and IGT after controlling for BMI and other possible confounding factors, suggesting that leptin is less important in the development of IGT. Wannamethee et al [37] reported that the association between leptin and type 2 diabetes disappeared in older men after adjusting for insulin resistance in a prospective cohort study. Similarly, Kanaya et al [38] reported that the association between leptin and the incidence of type 2 diabetes disappeared after adjusting for metabolic syndrome-related factors. However, Panarotto et al [39] reported that leptin is independently associated with IGT and type 2 diabetes in Caucasian females, although that study did not determine adiponectin. Therefore, the associations between leptin and impaired glucose metabolism may be mediated by insulin resistance and other factors.

The limitation of our study is that the cross-sectional design prohibits us from inferring a causal relationship. Second, most of our study subjects were obese because they were recruited from obesity clinics. Therefore, the study subjects may be more insulin-resistant and thus skew the data; however, after log-transforming our data (which was carried out before data analysis and which we have not shown in this paper) and adjusting for potential confounding factors, the results remained valid and the significance should not be ignored. Third, we did not collect nutritional information from the study subjects; therefore, possible associations between nutritional effects, adipocytokines and insulin resistance are not clear in our study.

Obesity is associated with the development of the metabolic syndrome, a cluster of metabolic abnormalities, including hypertension, abnormal glucose metabolism, dyslipidemia, and hyperuricemia. Insulin resistance and compensatory hyperinsulinemia may be a potential link between obesity [40]. Therefore, early detection of insulin resistance is important for early intervention and prevention of obesity-related comorbidities.

In conclusion, we found associations between leptin and adiponectin and obesity and related metabolic disorders, although the associations were in opposite directions. Leptin and adiponectin were both associated with insulin resistance and hyperinsulinemia independently of obesity, suggesting that leptin and adiponectin may be involved in the pathophysiologic link between obesity and insulin resistance. However, low levels of adiponectin, but not leptin, were associated with 2-hour glucose levels and IGT, suggesting that adiponectin is a potential determinant for the progression of insulin resistance to type 2 diabetes, and low levels of adiponectin might predict the increased risk of developing impaired glucose metabolism, type 2 diabetes, premature mortality and cardiovascular disease.

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非糖尿病女性之脂肪細胞激素與胰島素阻抗之相關性研究

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肥胖是胰島素阻抗及第二型糖尿病的危險因子。最近發現，由脂肪細胞所分泌的一些蛋白質 (瘦體素、酯聯素) 與胰島素阻抗性有關。本篇研究目的在於探討非糖尿病女性其脂肪細胞酵素包括瘦體素、酯聯素與胰島素抗阻及葡萄糖不耐症之間的相關性。個案選自在 **2003** 年 **2** 月至 **2004** 年 **2** 月間小港醫院準備參加減重門診的婦女，排除已知有糖尿病的患者以及目前正在使用降血壓、降血脂及降血糖的藥物後，共有 **190** 位個案。以問卷收集個案的基本資料，生活習慣，過去疾病史及藥物史。所有個案在隔夜空腹後抽血分析血糖、總膽固醇、高密度膽固醇、三酸甘油酯、胰島素及瘦體素、酯聯素。所有個案在給予口服 **75** 克葡萄糖水試驗後 **2** 小時，抽血測量血糖值以判斷個案是否有葡萄糖不耐症。計算 **HOMA-IR** 作為胰島素抗阻程度的指標，並且測量血壓、腰圍及 **BMI**。統計分析以皮爾斯相關分析 **BMI**、胰島素、瘦體素及酯聯素間的相關性；以複迴歸分析控制相關因子後分析瘦體素、酯聯素與胰島素阻抗的相關性。多變數分析的結果顯示，在控制了包括 **BMI** 在內的相關變數後，瘦體素及酯聯素兩者分別與 **HOMA-IR** 或空腹胰島素濃度有顯著的統計相關，其中瘦體素與 **HOMA-IR** 及空腹胰島素濃度為正相關，而酯聯素與 **HOMA-IR** 及空腹胰島素濃度為負相關。而控制了包括 **BMI** 在內的可能干擾因子後，**adiponectin** 與葡萄糖不耐症仍有顯著的統計相關，瘦體素則無統計上的顯著差異。在控制了肥胖的因素後，瘦體素和酯聯素分別與胰島素抗阻性及空腹胰島素濃度之間仍有顯著統計相關，推論分泌自脂肪細胞的瘦體素及酯聯素可能與肥胖者發生胰島素阻抗的機轉有關。而在控制了肥胖等相關因子後，酯聯素與葡萄糖不耐症仍有統計上顯著差異，推論較低的血清酯聯素濃度可能與發生血糖代謝異常或糖尿病有相關，而瘦體素則較無關。

關鍵詞：脂肪細胞激素，酯聯素，胰島素抗阻性，瘦體素，肥胖
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