Original Research

Anthropometric Characteristics, Dietary Patterns and Risk of Type 2 Diabetes Mellitus in Vietnam

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Key words: body fat, protein intake, diabetes, type 2 diabetes mellitus, Vietnam

Objective: To determine the impact of anthropometric characteristics and dietary patterns on Type 2 diabetes mellitus in Vietnam.

Methods: Data from 144 subjects (9m/39f newly diagnosed diabetics; 18m/78f control subjects) were analyzed in this case-control study. Height, weight, waist and hip circumferences and percent body fat were measured. Dietary intakes were assessed by 24-hour recall on three non-consecutive weekdays. Fasting blood samples were collected for the analysis of plasma glucose, fructosamine, protein and lipid concentrations.

Results: Although the body mass index (BMI, kg/m^2) was similar between diabetic and control subjects, diabetic subjects had significantly greater percent body fat (31.1 ± 5.8% *vs.* 27.7 ± 6.2%) and waist-hip ratios (WHR, 0.91 ± 0.07 *vs.* 0.86 ± 0.08). Diabetic subjects had higher intakes of protein ($p < 0.01$), especially animal protein ($p < 0.001$), and consumed more meat ($p < 0.01$) than control subjects. Percent body fat and WHR were positively associated with diabetes (odds ratios [OR] 1.53 [95%CI 1.29–1.79] and 1.09 [95% CI 0.89–1.58], respectively) as were protein intake (OR 1.21 [95% CI 1.12–1.31]) and animal protein intake (OR 1.18 [95% CI 1.10–1.26]).

Conclusions: This study indicates that percent body fat and WHR are risk factors associated with diabetes even when the BMI is normal. Evolving dietary patterns with increasingly more protein and meat consumption may also contribute to the deterioration of glucose metabolism among Vietnamese people.

INTRODUCTION

The prevalence of diabetes mellitus is increasing worldwide [1]. This increase is primarily the result of lifestyle changes known as the "Nutrition Transition," characterized by overconsumption of food, increased consumption of total fat, animal fat, and protein, and decreased physical activity [2]. The relationship between Type 2 diabetes mellitus (T2DM) and dietary intake and physical activity has been examined in several recent studies [3–5].

In Vietnam, as in other parts of Asia, the economy has been rapidly expanding during the last decade, leading to profound changes in society. As a result, there is a polarization in disease patterns, with undernutrition and its related diseases coexisting with chronic diseases such as diabetes and obesity that are typically associated with industrialized populations [2,6]. According to a screening survey conducted on 2,932 people in Ho Chi Minh City in 2001, the prevalence of diabetes in rural and urban areas was 4.8% and 6.9%, respectively. The reported prevalence of diabetes in urban areas in 2001 was approximately 2.8 times higher than that observed in 1993 [7]. Thus, diabetes mellitus has become a major public health problem in Ho Chi Minh City. In addition, diabetes and its complications are risk factors for chronic diseases with significant morbidity and mortality [8,9]. A recent study of 175 diabetic patients found that 41% had hypertension, 27% had cerebral circulation disorders, and 19% had myocardial ischaemia [10]. Although cross-sectional screening surveys suggest several risk factors that may be associated with diabetes, there are no studies investigating risk factors for diabetes in community settings in Vietnam. The purpose of the present study, therefore, was to determine the impact of anthropometric

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characteristics and dietary patterns on Type 2 diabetes mellitus in Vietnam.

MATERIALS AND METHODS

Study Population

The results of a previous screening survey of 2,932 randomly selected adults indicated a 3.8% adjusted prevalence rate of diabetes in Ho Chi Minh City (urban and rural areas combined) [7]. Approximately 40% of the diabetic subjects identified were unaware of their condition; 50 of these individuals who were newly diagnosed with T2DM (10 m/40 f) were recruited by a simple random sampling method to create the case group. The control group consisted of 100 normoglycemic subjects who were matched for age (± one year), sex and place of residence to case subjects. Matching for place of residence was done with consideration of the same ward for urban or the same village for rural areas. Two control subjects were chosen for each case subject. The sample size of this study was calculated using $\alpha = 0.05$, $\beta = 0.2$ and the standard effect size = 0.5. This study was conducted for 2 months from April to May 2001. Further details of subject recruitment are reported in the screening survey [7].

Diabetes was diagnosed based on the 1998 WHO diagnosis criteria [11] and the American Diabetes Association diagnosis criteria [12]. After participating, the diabetic subjects were immediately referred to the Diabetes Care Unit of the Nutrition Center of Ho Chi Minh City for treatment.

This study was approved by the Research and Ethnical Review Board of the Health Service of Ho Chi Minh City and written informed consent was obtained from all participants.

Anthropometry Measurements

Body weight, height, waist and hip circumferences, and percent body fat were measured with the participant in the standing position wearing light clothing and no shoes. Body weight was determined using a digital scale Tanita 1609 (Tanita, Tokyo, Japan) to the nearest 0.1 kg. Height was measured with a portable Seca stadiometer 208 (Vogel & Halke, Hamburg, Germany) to the nearest 0.1 cm. Body mass index (BMI) was computed as the ratio of weight (kg) per height squared (m^2). Waist circumference was measured at the minimum circumference between the umbilicus and iliac crest; hip circumference was measured at the widest circumference around the buttocks; waist-to-hip ratio was calculated from these circumferences. Percent body fat was determined by bioelectrical impedance using a body fat analyzer (BF-511, Tanita Co. Ltd., Tokyo, Japan) which has four tactile electrodes that fit on the soles of the feet. With the subject standing on the sole electrodes, the microprocessor-controlled switches and impedance analyzer are started and segmental resistance of the right leg, left leg and trunk are measured. Percent body fat is calculated from the sum of each body segment using gender-specific equations provided by the manufacturer. Prior to the measurement, the subjects were asked to remove all metallic objects, and washed and dried their feet thoroughly. Blood pressure was measured twice by mercury sphygmomanometer in the sitting position after participants rested for at least 5 minutes. The mean of the two values was used in the analysis.

Assessment of Socio-Economic Status and Lifestyle

Each participant completed a questionnaire assessing the family history of diabetes (is there anyone in your family who has diabetes?), smoking habit (yes or no) and socio-economic status, including level of education and household income. Education level was classified into three groups: low including illiterate, literate, and primary school; medium including junior high school; and high including high school, college and university. Household income was estimated based on the number of valuable household items owned among a total of 12 items and classified into three groups: low ($\leq$4); medium (5–8) and high ($>$8). This indirect way of evaluating household income has been shown to be more practical for community surveys than directly asking about family income [13].

Dietary and Nutrient Assessments

All subjects were asked to recall all foods consumed during the previous 24 hours on three nonconsecutive weekdays [14]. Tableware items such as bowls, dishes, spoons and glasses in commonly-used sizes, food models and pictures of common foods were used to assess food intake. Twenty-four hour energy and nutrient intakes for the 3 days were determined with computer software based on Vietnamese food composition tables [15–16]. The means of these values were used in the analysis.

Analytical Measurements

A single, fasting 7 mL venous blood sample was collected and centrifuged immediately. Aliquots of plasma were stored at −20°C in Vietnam and then transported on dry ice to Japan where they were stored at −80°C until analysis. Plasma glucose was measured by the glucose oxidase method and fructosamine by the reduction of nitro-blue tetrazorium (SRL Co. Ltd, Tokyo, Japan). Plasma total cholesterol and triacylglycerol concentrations were determined by enzymatic assay (Wako Pure Chemicals Co., Ltd., Osaka, Japan). Plasma high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were determined by enzymatic assay (Daiichi Pure Chemicals Co., Ltd., Tokyo, Japan). Plasma protein and albumin concentrations were determined by assay kits (Wako Pure Chemicals Industries, Osaka, Japan).

Statistical Analysis

Data in the tables are presented as means or geometric means with 95% confidence intervals (CIs) for each gender and for the total groups. Plasma glucose, fructosamine, HDL-C, LDL-C, triacylglycerol, intake of several nutrients (i.e. animal lipid, cholesterol, vitamin C, sodium, magnesium) and intake of selected food items (such as rice, meat, fish, vegetable and fruits intake) were $\log_{10}$ transformed to normalize the distributions. Statistical analyses were done using SPSS for windows 10.0 (SPSS, Chicago, IL).

The independent sample *t*-test was used to compare means and test for significant differences in anthropometric and biochemical indices, nutritive intakes and the quantity of food consumed between the groups. The conditional logistic regression model, adjusted for family history of diabetes, socio-economic status, smoking habit, and energy intake, was used to analyze the relationship between the various factors and diabetes; associations were considered statistically significant at $p < 0.05$.

RESULTS

A total of 150 subjects were enrolled in this study; however, two diabetic subjects (one male and one female) were excluded from the analysis due to acute influenza during the dietary data collection period. As a result, four matched controls (two males and two females) were also excluded. Thus, data from 144 participants were available for analysis.

The clinical characteristics and biochemical parameters of the study population are shown in Table 1. There were no significant differences in the gender-adjusted BMI between diabetic subjects and controls. However, diabetic subjects had significantly higher levels of body fat and WHR than controls (Table 1). Compared with the controls, diabetic subjects had significantly higher fasting plasma glucose and fructosamine concentrations as well as significantly higher concentrations of plasma total cholesterol, LDL-C and triacylglycerol (Table 1).

The energy and nutrient intakes from the repeated 24-hour recalls are shown in Table 2. Significantly higher intakes of protein ($p < 0.01$) especially animal protein ($p < 0.001$) were observed in diabetic compared to control subjects. Diabetic subjects had lower intakes of carbohydrates ($p < 0.01$) including less rice ($p < 0.05$) and greater consumption of meat ($p < 0.01$) than control subjects (Table 3). Micronutrients including cholesterol, Vitamin C, calcium, sodium, potassium and magnesium were not significantly different between the groups (data not shown).

After adjusting for family history of diabetes, socio-economic status, smoking habit and energy intake, conditional logistic regression revealed that diabetes was significantly and positively associated with percent body fat, WHR, protein intake and specifically animal protein intake (Table 4). Odds ratios (OR) for the positive associations between percent body fat and WHR and diabetes were 1.53 (95% CI 1.29–1.79) and 1.09 (95% CI 0.89–1.58), respectively. There was a positive association between diabetes and protein intake (OR 1.21 [95% CI 1.12–1.31]) as well as animal protein intake (OR 1.18 [95% CI 1.10–1.26]). Meat consumption was positively associated

Table 1. The Clinical Characteristics and Biochemical Parameters of the Study Population

Variables	Male		Female		Total	
	Diabetes n = 9	Controls n = 18	Diabetes n = 39	Controls n = 78	Diabetes n = 48	Controls n = 96
General and Clinical Characteristics						
Age	57.7 (51.5–63.9)	58.1 (53.5–62.7)	56.9 (53.8–60.0)	56.0 (53.6–58.4)	57.1 (54.7–60.3)	56.6 (54.4–58.8)
Weight (kg)	60.5 (54.8–66.2)	56.1 (52.2–60.0)	50.1 (47.6–52.6)	52.8 (50.5–55.1)	52.1 (49.6–54.6)	53.4 (51.4–55.4)
Height (cm)	161 (157–164)	156 (154–159)	151 (149–153)	152 (150–153)	153 (151–155)	153 (151–154)
BMI	23.5 (21.2–25.9)	22.9 (21.5–24.2)	21.9 (20.9–23.1)	22.9 (22.0–23.8)	22.5 (21.3–23.3)	22.9 (22.1–23.7)
Body fat (%)	28.3 (24.8–31.8)†	22.1 (19.8–24.3)	31.8 (30.0–33.6)†	28.9 (27.6–30.2)	31.1 (29.7–32.9)††	27.7 (26.5–28.9)
WHR	0.93 (0.91–0.95)	0.90 (0.87–0.93)	0.90 (0.88–0.92)†	0.85 (0.83–0.87)	0.91 (0.89–0.93)†	0.86 (0.84–0.88)
SBP (mmHg)	145 (132–157)	139 (126–151)	133 (125–141)*	124 (120–128)	135 (128–142)*	127 (122–131)
DBP (mmHg)	88.3 (81.0–95.6)	85.0 (77.9–92.1)	78.6 (74.8–82.4)	76.8 (74.2–79.4)	80.4 (76.9–83.9)	78.3 (75.7–80.8)
Family history of diabetes (Yes/No)	4/5	1/17	4/35	5/73	8/40	6/90
Smoking (Yes/No)	8/1	14/4	0/39	0/78	8/40	14/82
Biochemical Parameters						
Glucose (mg/dL)+	161 (142–183)††	99 (95–103)	188 (176–202)††	96 (93–99)	183 (172–195)††	97 (94–99)
Fructosamine (μmol/L)+	453 (404–508)††	287 (261–306)	476 (437–517)††	278 (267–290)	471 (439–506)††	281 (259–304)
TC (mg/dL)	247 (220–273)*	215 (194–236)	247 (233–261)†	223 (214–232)	247 (235–259)††	221 (213–230)
HDL-C (mg/dL)+	48.7 (43.3–54.8)	55.0 (49.3–61.3)	51.9 (48.9–55.0)	52.4 (50.3–54.5)	52.3 (48.7–54.1)	52.8 (50.5–55.3)
LDL-C (mg/dL)+	152 (133–174)	125 (110–142)	151 (142–161)*	134 (127–142)	151 (138–165)†	132 (118–149)
TG (mg/dL)+	230 (132–399)*	128 (103–161)	174 (146–207)*	148 (131–168)	184 (154–219)†	145 (129–162)
Total Protein (g/dL)	8.9 (8.2–9.6)	8.2 (8.0–8.4)	8.4 (8.2–8.6)	8.6 (8.4–8.8)	8.5 (8.3–8.7)	8.5 (8.3–8.7)
Albumin (g/dL)	5.1 (4.8–5.4)	4.9 (4.8–5.0)	4.9 (4.8–5.0)	5.0 (4.9–5.1)	4.9 (4.8–5.0)	4.9 (4.8–5.0)

Data are n, or mean or geometric mean with 95% CI in parentheses. + Statistical analyses were performed on $\log_{10}$ transformed variables.

BMI = body mass index, WHR = waist-hip ratio, SBP = systolic blood pressure, DBP = diastolic blood pressure, TC = total cholesterol, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol, TG = triacylglycerol.

Significantly different means between diabetic subjects and controls for each sex: * $p < 0.05$, † $p < 0.01$, †† $p < 0.001$.

Table 2. Average Dietary Intake of Energy, Macronutrients of the Study Population

Variables	Male		Female		Total	
	Diabetes n = 9	Controls n = 18	Diabetes n = 39	Controls n = 78	Diabetes n = 48	Controls n = 96
Energy (kcal)	2002 (1809–2195)	1926 (1813–2039)	1612 (1550–1674)*	1711 (1655–1767)	1685 (1610–1760)	1746 (1694–1798)
Protein (g)	87.7 (80.3–95.1)†	74.6 (69.3–79.9)	73.3 (69.8–76.8)	69.7 (67.2–72.2)	76.0 (72.5–79.5)†	70.6 (68.2–72.9)
Animal protein (g)	52.5 (45.2–59.7)†	40.7 (36.2–45.2)	44.5 (41.8–47.2)††	37.9 (35.9–39.9)	46.0 (43.3–48.7)††	38.4 (36.6–40.2)
Lipid (g)	53.5 (46.1–60.9)	48.5 (43.2–53.8)	43.6 (40.3–46.9)	42.9 (40.5–45.2)	45.5 (42.2–48.8)	43.9 (41.7–46.1)
Animal lipid (g)+	27.1 (22.0–32.1)	22.0 (17.8–27.1)	20.6 (18.8–22.6)	22.4 (20.3–24.8)	21.4 (19.6–23.5)	22.3 (20.6–24.2)
Carbohydrate (g)	290 (246–334)	287 (267–307)	232 (224–241)††	262 (252–271)	243 (231–255)†	266 (258–275)

Data are mean or geometric mean with 95% CI in parentheses. + Statistical analyses were performed on $\log_{10}$ transformed variables.
Significantly different means between diabetic subjects and controls for each sex: * $p < 0.05$, † $p < 0.01$, †† $p < 0.001$.

Table 3. Average Food Intake as Measured by Repeated 24-Hour Recalls

Variables	Male		Female		Total	
	Diabetes n = 9	Controls n = 18	Diabetes n = 39	Controls n = 78	Diabetes n = 48	Controls n = 96
Rice (g)+	287 (248–332)	294 (274–317)	234 (223–246)*	257 (246–268)	245 (232–258)*	262 (253–272)
Oil (g)	23.9 (19.0–28.8)	18.9 (15.2–22.6)	18.8 (16.8–20.8)	18.3 (16.9–19.7)	19.8 (17.9–21.7)	18.4 (17.0–19.8)
Meat (g)+	168 (136–207)*	142 (126–162)	144 (130–160)†	116 (107–125)	148 (135–163)†	120 (112–129)
Fish (g)+	40.1 (19.9–80.8)	35.2 (24.4–50.6)	47.5 (35.7–63.0)	44.1 (37.7–51.7)	45.7 (39.1–59.5)	42.4 (36.7–49.1)
Vegetables (g)+	154 (129–182)	151 (129–176)	145 (132–159)	147 (132–163)	146 (135–159)	147 (135–161)
Fruits (g)+	87 (46–166)	106 (59–191)	113 (84–152)	128 (105–156)	112 (86–146)	118 (97–144)

Data are mean or geometric mean with 95% CI in parentheses. + Statistical analyses were performed on $\log_{10}$ transformed variables.
Significantly different means between diabetic subjects and controls for each sex: * $p < 0.05$, † $p < 0.01$, †† $p < 0.001$.

Table 4. Associated Factors or Diabetes (Adjusted for Family History of Diabetes, Socio-Economic Status, Smoking, Energy Intake)

Variables	Odds ratios	*p*-value
WHR	1.09 (0.89–1.58)	0.001
Percent body fat	1.53 (1.29–1.79)	0.000
Protein intake	1.21 (1.12–1.31)	0.000
Animal protein intake	1.18 (1.10–1.26)	0.000
Carbohydrate intake	0.98 (0.94–0.99)	0.001
Rice intake	0.99 (0.98–0.99)	0.027
Meat intake	1.03 (1.01–1.04)	0.000

WHR = waist-hip ratio. Values in parentheses are 95% confidence intervals.

with diabetes, whereas the association between rice intake and diabetes was somewhat protective (Table 4).

DISCUSSION

The prevalence of diabetes in Vietnam has been increasing rapidly and constitutes a significant public health problem and priority. Understanding the characteristics of diabetes in Vietnam is essential for developing programs to prevent and control this disease.

In the current study, we found that percent body fat and WHR were associated with an increased risk of diabetes. Overweight, using a BMI cut-off point of 25 kg/m^2, as well as central obesity, have been identified as risk factors for diabetes [5,17–18]. Whereas the BMI level of diabetic subjects in our study was within the normal range, diabetic subjects had higher percentages of body fat and WHR compared with controls. Although percent body fat and BMI are correlated [18], a high percent body fat and a high WHR in the context of a normal BMI may be an anthropometric characteristic of diabetes in Vietnam. Our finding supports the WHO expert conclusion that ". . .Asians have a higher body fat than Caucasians of the same age, sex and BMI. Also, the proportion of Asian people with risk factors for Type 2 diabetes and cardiovascular disease is substantial even below the existing WHO-BMI cut off point of 25 kg/m^2" [19]. Moreover, a recent study found that percent body fat was higher in Vietnamese than Japanese people [18]. Additional studies indicate that abdominal fat and percent body fat are increasing in Vietnamese people, especially in females [20–21]. As the relationship between percent body fat and diabetes becomes clearer, percent body fat data could be helpful in predicting future increases in diabetes in Vietnam.

The accumulation of body fat is a continuous process that is influenced by energy and fat intake in excess of requirements, decreased physical activity and a sedentary lifestyle [22]. Although the percent body fat of the diabetic subjects in our study was higher than that of controls, the energy intake of the diabetic subjects was similar compared to the controls. We believe our dietary assessments accurately reflect the eating habits of the subjects because we did 24-hour food recalls on three nonconsecutive weekdays and used standard tableware items, food models and pictures of commonly eaten foods [14]. Furthermore, the diabetic subjects were unaware of their condition during the study period, so it is unlikely they intentionally modified their diets. However, a limitation of our study is that we were unable to assess physical activity. Future studies examining the relationships between body composition and diabetes should include assessments of physical activity and energy expenditure.

Dietary intake appears to be one of the most important factors related to diabetes [3,4], and the dietary patterns of the Vietnamese people are changing [2]. In comparison with earlier studies on dietary intakes of the Vietnamese people [21,23–25], protein intake and specifically animal protein intake and consumption of meat were higher in this study than previously reported. Furthermore, we found significant positive associations between diabetes and protein intake and between diabetes and animal protein intake. These findings are in agreement with other studies showing positive associations between meat intake and increased risk of diabetes [3,26–28].

The role of dietary protein in the pathogenesis of diabetes may be through increased glucagon secretion. Increased protein intake may result in increased concentrations of gluconeogenic amino acids, which stimulate glucagon secretion. In subjects with T2DM, high glucagon concentrations despite adequate insulin concentrations appear to partially explain high blood glucose concentrations [29]. Dietary protein is also known to stimulate insulin secretion [29] and hyperinsulinemia increases insulin resistance [30], a known risk factor for the development of T2DM. Although the relationship between protein intake and risk of diabetes is consistent with previous studies [31–32], the effect of high protein intakes on the development of diabetes is purely speculative at this stage. Further evaluation is needed in the Vietnamese people and among other populations with dietary intake patterns that are becoming increasingly richer in protein.

Consistent with other studies [33–34], we also found that diabetic subjects had significantly higher total cholesterol, LDL-cholesterol and triacylglycerol concentrations than controls. Because of the danger presented by early-onset diabetes on the incidence of the metabolic syndrome and the increased risk of coronary events [8,9,35], early detection and control of diabetes is critical.

In conclusion, our results indicate that elevated percent body fat and WHR are associated with an increased risk of developing diabetes in Vietnamese people, even when the BMI is within normal limits. Our data also suggest that higher intakes of protein, especially meat protein may also contribute to the deterioration of glucose metabolism in Vietnam.

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