Background  The correlation between body mass index (BMI)/obesity and blood pressure/hypertension has not been confirmed in diabetic patients. This study analyzed the association in Taiwanese adult patients with type 2 diabetes mellitus (T2DM).

Methods and Results  The National Health Insurance data of 89,857 adult patients (41,398 men and 48,459 women; aged ≥18 years with mean ± SD of 62.2±11.3 years) interviewed by questionnaire were analyzed, taking into account the potential confounding of age, sex, diabetic duration, smoking and parental hypertension. Prevalence of obesity (BMI ≥25 kg/m²) was 39.3% and 41.7% in the diabetic men and women, respectively; and hypertension was 54.5% in both sexes. Hypertension increased significantly with increasing age and BMI. The adjusted odds ratio (OR) for hypertension for every 1 kg/m² increment of BMI was 1.16 (1.15–1.17) and 1.13 (1.12–1.14) for men and women, respectively. The correlation between BMI and hypertension/blood pressure extended throughout BMI levels to the nonobese range. For men, adjusted OR for BMI <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9 and ≥30.0 kg/m² were 1.00, 1.23 (1.07–1.41), 1.78 (1.55–2.05), 3.06 (2.66–3.53) and 6.59 (5.56–7.82), respectively; and were 1.00, 1.09 (0.97–1.22), 1.49 (1.32–1.68), 2.32 (2.06–2.60), 4.40 (3.84–5.05), respectively, for women. For every 1 unit BMI increase in patients without a hypertension history, the systolic and diastolic blood pressures significantly increased by 0.618 and 0.447 mmHg for men; and by 0.637 and 0.462 mmHg, respectively, for women.

Conclusions  BMI/obesity is significantly linked to blood pressure/hypertension throughout the range of BMI in diabetic patients in either sex regardless of a previous hypertension history. (Circ J 2007; 71: 1749–1754)

Key Words: Blood pressure; Body mass index; Hypertension; Obesity; Taiwan; Type 2 diabetes mellitus

The Framingham Offspring study estimated that approximately 65% and 75% of the hypertension risk in women and men, respectively, could be attributed to being overweight or obese! Although this link was well confirmed in the general populations of the US2,3 and Norway4 in more recent epidemiologic studies, the impact of obesity on morbidity and mortality may not be similar among different ethnic groups5–10 Furthermore, because the cutoffs for body mass index (BMI) used to define obesity or overweight are different for Asian populations11,12 it is necessary to examine whether the recommended cutoffs are associated with hypertension risk in Asian people.

Age is an independent risk factor for hypertension13 but the impact of body weight on blood pressure could be different between men and women1 Family history and smoking are also important risk factors for hypertension, but they were not always considered simultaneously as confounders in the evaluation of the relationship between BMI and hypertension2–4 Because diabetic patients are characterized by various metabolic disturbances that can lead to hypertension, the relative impact of obesity on blood pressure and hypertension might level off in these patients. Therefore, the association between BMI/obesity and blood pressure/hypertension observed in the general population should not be extrapolated to diabetic patients without evidence derived directly from this unique group of individuals. To the best of our knowledge, the prevalence of obesity in the Taiwanese diabetic patients is not well defined, and whether obesity is associated with hypertension in these patients remains to be confirmed. Therefore, this study evaluated the prevalence of obesity and its correlation with hypertension in adult Taiwanese patients with type 2 diabetes mellitus (T2DM) in the respective sexes, taking into account the potential confounding effects of age, diabetic duration, smoking and parental hypertension.

Methods

Study Subjects

The study was approved by the Ethics Committee of the Department of Health of Taiwan. Because more than 96% (with the exemption of persons involved in military services and those subject to criminal sanction, etc) of the total population of Taiwan has been covered by the compulsory and universal National Health Insurance (NHI) since March 1995, almost all diabetic patients have been using the NHI!4–18 Therefore, the clinical settings’ databases claiming for the NHI are appropriate for deriving a national sample of diabetic patients. The assembly of such a national sample has been described in detail elsewhere14–18 In brief, the...
total number of diabetic patients identified in the NHI database was 536,159, from which a total of 256,036 were identified from 66 hospitals and clinics located evenly throughout Taiwan. To create a cohort of 90,000 patients (approximately one-sixth of the total number of diabetic patients in Taiwan during the period) for long-term follow-up, 128,572 cases were randomly selected, supposing a response rate of 70%.

**Table 1 Percentage Distribution of Body Mass Index by Age and Sex**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years)</th>
<th>&lt;18.5</th>
<th>18.5–22.9</th>
<th>23.0–24.9</th>
<th>25.0–29.9</th>
<th>≥30</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Both sexes</strong></td>
<td>&lt;40</td>
<td>4.2</td>
<td>27.4</td>
<td>18.8</td>
<td>34.1</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>40–49</td>
<td>2.6</td>
<td>27.4</td>
<td>23.7</td>
<td>36.3</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>50–59</td>
<td>2.3</td>
<td>29.0</td>
<td>26.0</td>
<td>34.9</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>60–69</td>
<td>2.9</td>
<td>30.9</td>
<td>25.5</td>
<td>34.2</td>
<td>6.5</td>
</tr>
<tr>
<td>≥70</td>
<td>4.2</td>
<td>35.6</td>
<td>24.8</td>
<td>30.1</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>3.1</td>
<td>31.3</td>
<td>25.0</td>
<td>33.5</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td>&lt;40</td>
<td>6.6</td>
<td>29.0</td>
<td>16.6</td>
<td>31.3</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>40–49</td>
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<td>24.6</td>
<td>34.8</td>
<td>9.3</td>
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<td>3.1</td>
<td>30.4</td>
<td>24.2</td>
<td>34.6</td>
<td>7.7</td>
</tr>
<tr>
<td>≥70</td>
<td>4.5</td>
<td>35.7</td>
<td>23.2</td>
<td>30.0</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>3.4</td>
<td>31.2</td>
<td>23.7</td>
<td>33.3</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td>&lt;40</td>
<td>2.5</td>
<td>26.3</td>
<td>20.3</td>
<td>36.1</td>
<td>14.7</td>
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<td>31.3</td>
<td>26.6</td>
<td>33.6</td>
<td>5.7</td>
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</tr>
</tbody>
</table>

*P values for both sexes, men and women are all <0.001 by chi-square test.*

**Statistical Analyses**

BMI was divided into underweight, normal, overweight, and obesity I and II with the following respective cutoffs recommended for Asian populations: <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9 and ≥30.0 kg/m². Age was divided into the following subgroups: <40, 40–49, 50–59, 60–69 and ≥70 years. While evaluating the association between BMI/obesity and blood pressure/hypertension, age, sex, diabetic duration, smoking and parental hypertension were treated as potential confounders. A p-value <0.05 was considered as statistically significant.

The classification of T1DM was based on either of the following criteria: (1) diabetic ketoacidosis at the onset of diabetes or (2) the patients required insulin injections within 1 year of diagnosis of diabetes. If a patient was not diagnosed as T1DM, he/she was viewed as a patient with T2DM. Patients identified as T1DM or aged <18 years were not included into the present study. A total of 93,484 (response rate: 72.7%) patients completed the interview. After excluding 3,528 with T1DM, there were 89,956 patients identified as T2DM. Exclusion of patients aged <18 years yielded 89,857 cases (41,398 men and 48,459 women).

**Results**

The subjects had a mean (SD) age, diabetic duration and BMI of 62.2 (11.3) years, 7.2 (6.5) years and 24.6 (3.6) kg/m², respectively; and the respective prevalence of smoking, hypertension and parental hypertension was 30.6%, 54.5% and 18.9%.

Table 1 shows the percentage distribution of BMI by age...
More than 65% of the patients were overweight or obese (>40%) and less than one-third had a normal BMI. Obesity, especially with BMI ≥ 30 kg/m², was more prevalent in the younger patients; and small percentages of the patients were underweight.

Table 2 shows the OR and their 95% CI for hypertension. BMI either as a continuous variable or as a categorical variable was significantly associated with hypertension.

Table 3 shows the regression coefficients for SBP and DBP estimated by BMI. All of the models were significant and the regression coefficients were larger for patients without a hypertension history when compared with those with such a history.

Fig 2 shows the estimated SBP and DBP for the percentiles of BMI after adjustment for age, sex, diabetic duration, smoking and parental hypertension. The curves for the patients without a history of hypertension showed a steeper increase of SBP and DBP with increasing BMI than those for patients with a hypertension history.
The findings of this study suggested that BMI is a major and independent determinant of blood pressure and hypertension in adult Taiwanese patients with T2DM. At the recommended cutoff of BMI 25 kg/m\(^2\) for Asian people\(^{11}\), the prevalence of obesity was 39.3% for diabetic men and 41.7% for diabetic women (Table 1). These figures were much higher than the respective prevalence rates of 24.6% and 23.3% for the adult general population in Taiwan\(^{19}\). For BMI \(\geq 30\, \text{kg/m}^2\), the respective prevalence for men and women was 5.7% and 8.4% in the diabetic patients (Table 1), in contrast to 2.3% and 5.0% in the general population\(^{19}\).

The correlation between BMI/obesity and blood pressure/hypertension was consistently demonstrated in the different age groups of each sex (Fig 1) and after adjustment for confounders (Tables 2, 3, Fig 2). Despite the different distribution of BMI and obesity in the different age groups in each sex (Table 1), the association seemed to be independent (Tables 2, 3, Fig 1) and existed in patients with or without a history of hypertension (Table 3, Fig 2). However, as
shown in Table 3 and Fig 2, the relationship was stronger in those without a hypertension history, probably because of exclusion of the confounding effect caused by the use of antihypertensive agents.

In the US, women who are overweight or obese have a 3- or 6-fold higher risk of hypertension, respectively.20 These were very similar to the findings in the diabetic men of the present study (Table 2) when using BMI ≥25 kg/m² and ≥30 kg/m² as the cutoffs for overweight and obesity, respectively (as recommended for Caucasians). However, the diabetic women showed an increased risk with lesser magnitude than the diabetic men (Table 2).

The relative risk for hypertension associated with being overweight declines with age in the general population of the USA.21 The present study also showed a similar attenuation of the prevalence ratios of hypertension associated with increasing age in the diabetic patients (Fig 1). This result was because of the lower prevalence of hypertension in the younger patients and the relatively higher prevalence in the older ones in the lower BMI categories (Fig 1). The relationship between BMI and SBP or DBP seemed not to be limited to the range of obesity, but extended throughout the nonobese range (Table 2, Figs 1,2), though attenuation of the correlation between BMI and prevalence of hypertension was found at lower BMIs, especially in the diabetic women (Fig 1A).

In this study, when calculated from patients without hypertension history in the adjusted models (Table 3), a BMI increase of 1 kg/m² corresponded to an increase in SBP of 0.62 and 0.64 mmHg in men and women, respectively; and a respective increase in DBP of 0.45 and 0.46 mmHg. These were comparable to the findings in a previous study that showed a gain of 1 unit BMI corresponded to an increase in SBP of approximately 0.59 and 0.80 mmHg in men and women, respectively.21 The finding of an increase of BMI of 1 kg/m² with an increase of 11% and 13% in the unadjusted and adjusted risk for hypertension, respectively, in the diabetic women of the present study (Table 2) also confirmed with the finding of a 12% increase in the adjusted risk for hypertension in women in the US.22

Study Limitations

First, the cross-sectional approach did not provide evidence for causality. Second, although a self-reported BMI may overestimate because height is always over-reported and weight under-reported, especially at higher BMI.23-27 Therefore the prevalence of obesity could be underestimated and the risk for the obese group could also be biased. Third, blood pressure was based on self-reporting without actual measurement, so the accuracy of the reported blood pressure was unknown. It is also unclear whether the reported blood pressure levels were those before or after treatment with medications in patients taking antihypertensive agents. However, a reported blood pressure that the patients ordinarily had would more actually reflect the average blood pressure of the patients over a period of time rather than the measured value taken at the time of measurement.

In conclusion, diabetic patients have a high prevalence of obesity and hypertension, and BMI/obesity is strongly linked with hypertension and blood pressure, with the correlation extending towards the nonobese range. This relationship conforms to findings derived from general populations of other ethnicities.

Acknowledgments

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