ABSTRACT To study the prevalence of impaired fasting glucose (IFG) by age and gender in Thais and to estimate the cost of IFG screening initiated in selected age groups. All individuals who had their fasting plasma glucose measured as a part of yearly physical examination program from January 2002 to December 2004. None is known to be hyperglycemic. Participants were categorized into eight age groups. The age-specific prevalence of IFG was calculated and determined for the age and gender trends. The population estimated is based on Thailand 2002 census. Plasma glucose increased with age in both genders \( r = 0.30, P<0.01 \) for male and \( r = 0.36, P<0.01 \) for female. As a group, the mean plasma glucose was elevated in male compared to female \( (101 \pm 25 \text{ vs. } 93 \pm 19 \text{ mg/dl, } P<0.01) \). The age-specific plasma glucose was higher in male \( \text{(ANCOVA, } P<0.01) \). The overall estimated prevalence was 22.2\% for IFG \( (8.3 \text{ million people}) \) and 4.4\% for undiagnosed DM \( (1.8 \text{ million people}) \). The age trend was observed for the prevalence of undiagnosed hyperglycemia \( \text{(IFG and undiagnosed DM)} \). The age-specific prevalence of undiagnosed hyperglycemia was higher in male compared to female \( \text{(ANCOVA, } P<0.01) \). The probability of identifying these individuals improves if screening is performed at older age \( \text{(ANCOVA, } P<0.01) \). The fasting plasma glucose varies with age and gender. The epidemic of undiagnosed hyperglycemia is an imminent public health concern. Our findings provide an important information for establishing a screening program to prevent and control DM.

Key words: impaired fasting glucose, gender, age–specific prevalence, diabetes mellitus (DM), and screening program.

Introduction

Currently diabetes mellitus (DM) is a major cause of morbidity and mortality in Thailand\(^1\). Chronic hyperglycemia can lead to end–organ damage such as coronary artery, cerebrovascular, and end–stage renal diseases\(^2,3\). Up to half of patients with DM are unaware of their hyperglycemia, and the diagnosis of DM may not be discovered for several years\(^4,5\). Epidemiologic studies have suggested that a substantial number of DM patients already have chronic complications.
of DM at the time of diagnosis\(^5\). In addition, individuals with impaired fasting glucose (IFG) are usually asymptomatic and are at risk for DM and metabolic syndrome\(^6\). These patients can only be discovered by fasting plasma glucose measurement. Identification of these individuals is essential for DM prevention and control\(^7\). It is estimated that 9.6% of Thais have DM\(^1\). However, the age-specific prevalence of IFG using the recent American Diabetic Association (ADA) criteria in Thais is not known. The present article was designed to estimate and study the influence of age and gender on the prevalence of IFG and undiagnosed DM in Thais. This information is fundamental for establishing a screening program for these hyperglycemic disorders.

**Materials and Methods**

**Patients Selection**

All individuals who enrolled in a yearly physical examination program at one tertiary care medical center from January 2002 to December 2004. Most individuals lived in Bangkok and are working middle class. None is known to be hyperglycemic.

**Fasting Blood Glucose Measurement**

Early morning fasting venous blood samples were collected and determined for blood glucose levels, using the hexokinase-glucose-6-phosphate dehydrogenase method. Fasting is defined as no consumption of food or beverage other than water for at least 8 hours before testing.

**Diagnosis of DM and Impaired fasting Glucose**

The diagnosis of DM and IFG was based on the American Diabetic Association (ADA) criteria\(^8\). To determine the age trend of plasma glucose, we divided participants into eight groups as followed, the 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, and >60 years old groups. The age-specific plasma glucose was used to represent an average plasma glucose within each age group.

**Statistical Analysis**

All analysis was performed using Statistical Package for the Social Sciences (SPSS) (Chicago, IL) version 13 windows edition software. Mean (SE) were calculated for all continuous variables. Comparison of average plasma glucose level between genders was performed with two-sided unpaired t-test. The age-specific plasma glucose and prevalence of hyperglycemia were used to study the age trend. The relation of plasma glucose level, prevalence of hyperglycemia and age was determined by regression analysis. Analysis of covariances was used to determine the influence of age and gender. P value of less than 0.05 was considered statistically significance.

**Results**

**Demography**

There were 14,837 individuals who had their fasting plasma glucose measured during the study period. Fourty percent were male. The mean age of male and female are 43 ± 0.1 year vs. 42 ± 0.1 year, respectively, \(P = \text{NS}\).
Fasting Glucose Level Increases with Age and Is Higher in Male.

As a group, fasting glucose was 100.7 (0.2 mg/dl for male and 92.7 ± 0.2 mg/dl for female (P<0.01). Linear regression analysis suggested a weak but significant relationship between fasting glucose and age in both genders (r = 0.30 for male and r = 0.36 for female, p<0.01 for each). The age-specific plasma glucose was higher in male (ANCOVA, P < 0.01, figure 1).

![Figure 1](image)

**Figure 1** The age-specific plasma glucose levels by age and gender.

Prevalences of IFG and Undiagnosed DM Increase with Age and Are Higher in Male.

The distribution of plasma glucose was shown in figure 2. The proportions of participants with plasma glucose level ≥ 100 mg/dl, ≥ 110 mg/dl and ≥ 126 mg/dl were 26.6%, 10.6% and 4.4% respectively. The overall prevalence was 22.2% for IFG and 4.4% for undiagnosed DM. Both IFG and undiagnosed DM were more common in older individuals (figure 3, r = 0.97 for IFG and r = 0.99 for undiagnosed DM, P < 0.01 each, figure 4). Furthermore, when adjusted for age, IFG and undiagnosed DM were more prevalent in male than female (ANCOVA, P < 0.01, figure 3).
Figure 2 Distribution of fasting plasma glucose in Thai aged ≥25 years old. The frequency of distribution is expressed as percentage of population.

Figure 3 The age-specific IFG and undiagnosed DM prevalence by age and gender. The IFG is shown as open circle in male and closed circle in female. For undiagnosed DM, the open square represents male and closed square represents female. Both IFG and undiagnosed DM are more prevalent in male than female (ANCOVA, *P<0.01, each).
Figure 4  The cumulative prevalence of undiagnosed hyperglycemia (IFG and undiagnosed DM)
There is a strong and significant association between the prevalence of undiagnosed hyperglycemia and age ($r = 0.99$, *$P<0.01$, each).

Economy of FG Screening

Based on Thailand 2002 census, the estimated people with IFG and undiagnosed DM would be an astonishing of 10.1 millions (1.8 millions for undiagnosed DM and 8.3 millions for IFG, table 1). We combined the data of IFG and undiagnosed DM to calculate the prevalence of undiagnosed hyperglycemia ($\geq 100$ mg/dl). The age trend of the undiagnosed hyperglycemic was then analyzed using the regression model. As shown in figure 5, there was a linear relationship between the prevalence of undiagnosed hyperglycemia and age ($r = 0.98$, $P<0.01$). It strongly suggests that the probability of discovering the undiagnosed hyperglycemia improves when screening is performed at older age (ANCOVA, $P<0.01$).
Table 1: This table will help to estimate the total number of those who may have DM or IFG when we classify by age and sex.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>IFG Male</th>
<th>IFG Female</th>
<th>IFG All</th>
<th>DM Male</th>
<th>DM Female</th>
<th>DM All</th>
<th>IFG + DM Male</th>
<th>IFG + DM Female</th>
<th>IFG + DM All</th>
</tr>
</thead>
<tbody>
<tr>
<td>25–29</td>
<td>337791</td>
<td>69825</td>
<td>365132</td>
<td>12396</td>
<td>9010</td>
<td>20865</td>
<td>350187</td>
<td>78834</td>
<td>385997</td>
</tr>
<tr>
<td>30–34</td>
<td>508454</td>
<td>117097</td>
<td>582340</td>
<td>35147</td>
<td>5666</td>
<td>37570</td>
<td>543600</td>
<td>122763</td>
<td>619910</td>
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<tr>
<td>35–39</td>
<td>700249</td>
<td>171044</td>
<td>852139</td>
<td>68479</td>
<td>16486</td>
<td>83084</td>
<td>768727</td>
<td>187530</td>
<td>935223</td>
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<tr>
<td>40–44</td>
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<td>321332</td>
<td>1020744</td>
<td>40167</td>
<td>798433</td>
<td>361499</td>
<td>1146708</td>
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<tr>
<td>45–49</td>
<td>762567</td>
<td>337367</td>
<td>1113100</td>
<td>138268</td>
<td>196303</td>
<td>392855</td>
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<tr>
<td>50–54</td>
<td>668151</td>
<td>297914</td>
<td>975616</td>
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<td>255258</td>
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<td>2876009</td>
<td>413879</td>
<td>418495</td>
<td>861514</td>
<td>1724877</td>
<td>3375246</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 5513630 2876009 8304391 1089801 715416 1805382 6603431 3591425 10109773

IFG = Impaired Fasting Glucose
DM = Diabetes Mellitus

Figure 5 This figure shows the trend of higher fasting blood sugar (FBS) with the age in Thais.
Discussion

Our study has confirmed the relation of plasma glucose and age. The role of insulin and other hormones such as leptin in glucose metabolism is well established (9). However, diet and exercise are considered to be important exogenous factors (10, 11). There is an increasing epidemic of overweight in the U.S. and other parts of the world. Excess weight and sedentary lifestyle in elderly have been shown to be associated with reduced insulin sensitivity (12). These confounding factors may contribute to the increased plasma glucose in aging Thais.

The prevalence reported in our study also increases with advancing age. The overall prevalence for undiagnosed DM was 4.4% for population age ≥ 25 years and was 6.2% for population age ≥ 35 years. The prevalence of IFG is relatively high in our study (22.2%). The explanation may be in part due to the change in the cut-off glucose level from 110 to 100 mg/dl for IFG diagnosis. For better comparison, we calculated the prevalence of plasma glucose ≥ 110 mg/dl. Using the old definition of IFG, the prevalence was 6.2% in our study. The prevalences reported in this study were slightly higher than those from the Inter ASIA Collaborative Group (1) ≥ 6.2% vs. 4.8% for undiagnosed DM and 6.2% vs. 5.4% for plasma glucose (110 mg/dl). The geographical and socioeconomic status of our participants may contribute to these differences.

Sex hormones play an important role in maintaining gender-specific phenotype. In addition, these hormones also participate in modulating physiological function of other organ systems (13). For example, the low bone mineral density in menopause is related to a decreased estrogen level. Furthermore, estrogen has been implicated to the sexual dimorphism of high blood pressure. Previous epidemiologic studies have suggested that there were more females with DM than males in certain parts of the world especially in the developing countries (14, 15). Though, few studies have reported the age structure and sex ratio of DM population, there was no direct comparison of age-specific DM prevalence between both genders. After adjusted for age, the age-specific plasma glucose is higher in male than female. This finding is not unexpected. Estrogen and its metabolites have been shown to participate in glucose metabolism. In an animal model of type 2 DM, 2-Hydroxyestradiol improves insulin sensitivity, lipid and blood pressure (18). In addition, leptin level is reported to be higher in female than male of similar age (17). When plasma glucose levels were plotted over age, the association of plasma glucose and age was relatively shift to the right in female. Based on this observation, the onset of IFG and DM may be postponed in female compared to male. Similar to the age trend of plasma glucose, the prevalence of undiagnosed hyperglycemia (IFG and undiagnosed DM) also increases with advancing age and is more common in male than female. The influence of age and gender on plasma glucose observed in this retrospective cross-sectional study may need to be confirmed in a prospective longitudinal study.
The fasting plasma glucose measurement has high sensitivity and specificity for the diagnosis of IFG\(^{18}\). It is relatively simple and inexpensive to perform. However, repeat fasting plasma glucose measurement and an oral glucose tolerance test may be required to confirm the diagnosis\(^{18}\). The US preventive task force has recommended screening for DM at the age of 45 years or older. However, the CDC Diabetes Cost-Effectiveness Study Group analyzed the lifetime costs and the benefit of DM screening in respect to long term complications, the quality of life, and survival\(^{7}\). They suggest that the screening may be more cost-effective at younger ages. Early identification and management of these hyperglycemic individuals would delay the development of DM complications and thus improve quality of life\(^{7}\).

The selection of appropriate target populations would improve the cost-effectiveness of screening. In our study, the probability of detecting individuals with hyperglycemia would increase from 34.7% to 39.5% if screening begins at the age of 35 and 45 years respectively. In Thailand, as a part of “Health for all” program, the majority of patients receive their care from government hospitals at very minimal cost. Though this policy has improved the care in a macro scale, it has not yet covered the health maintenance aspect. The screening for IFG would be best conducted in conjunction with DM education\(^{18}\). Individuals with IFG response well to nonpharmacological management such as dietary and lifestyle modifications\(^{10,11}\). Treating these individuals would delay DM onset and reduce the risk for metabolic syndrome.

Our study has presented a provisional data necessary for establishing a screening program in Thailand to control and prevent DM and its complications.

**CONCLUSIONS**

The case for screening for undiagnosed diabetes is probably somewhat stronger than it was before, because of the greater options for reduction of CVD, principally through the use of statins and antidiabetic drugs, and because of the rising prevalence of obesity and hence type 2 diabetes. However, there is also a good case for screening for IGT, with the aim of preventing some future diabetes and reducing CVD. Further recommendation is needed into the duration of undiagnosed diabetes, and whether the rise in blood glucose levels is linear throughout or whether there may be a slower initial phase followed by an acceleration around the time of clinical diagnosis. This study has implications for the appropriate time for a screening in normal healthy population and when screening would be repeated, thus this will be able integrate in Thai national health care plan in the near future as the preventive strategy.

**References**


บทความ การศึกษาเกี่ยวกับภาวะที่มีระดับน้ำตาลในเลือดสูงกว่ามาตรฐาน (Impaired fasting glucose; IFG) ใน adolescenced ของระดับน้ำตาลในเลือดสูงกว่ามาตรฐาน (Fasting blood sugar) ในอาสาสมัครจำนวน 14,837 ราย ที่มารักษาหายป่วยเป็นระยะที่ยาวนานกว่า 2545 – 2547 จำนวนรวมถึงอายุสูงสุดเป็น 8 กลุ่ม เพื่อคำนวณหาค่าความสุทธิของ IFG ในแต่ละกลุ่มเพื่อนักประชาชนไทยจากการตรวจวัดระดับน้ำตาลที่เพิ่มขึ้นในแต่ละช่วงอายุทั้งเพศชายและเพศหญิงโดยคู่มือประชาชนของประเทศไทยในปี 2002 มีค่าความสุทธิของโรคเพิ่มขึ้นระดับน้ำตาลเพิ่มขึ้นตามอายุทั้ง 2 เพศ (r=0.3, P<0.01) คำนวณค่าร้อยละของระดับน้ำตาลที่สูงกว่าปกติโดยมี age specific plasma glucose ในเพศชายอยู่ในเพศหญิง (101 ± 2 VS 93 ± 19 mg/dl, P<0.01 และ ANCOVA, P<0.01) เมื่อประมาณค่าที่สูงกว่ามาตรฐานของประเทศไทยพบว่ามีภาวะของ IFG ถึง 22.2% หรือประมาณ 8.3 ล้านคน และมีภาวะของโรคเบาหวานที่ไม่ได้รับการวินิจฉัยถึง 4.4% หรือประมาณ 1.8 ล้านคน ความน่าจะเป็นของการที่มีอายุมากขึ้นจะทำให้เกิดภาวะของโรคเบาหวานที่ยังไม่ได้รับการวินิจฉัยเพิ่มขึ้น (undiagnosed DM) โดยมี age–specific ของภาวะ IFG และภาวะของโรคเบาหวานที่ยังไม่ได้รับการวินิจฉัยของเพศชายมากกว่าเพศหญิง (ANOVA, P<0.01) ความเป็นไปได้ที่สามารถตรวจจับ (screening) ภาวะความผิดปกติเหล่านี้จะเพิ่มขึ้นเมื่อตรวจจุดอายุมากขึ้น ภาวะระดับของ undiagnosed hyperglycemia เป็นสิ่งที่ระบบสาธารณสุขควรสนใจและงานวิจัยนี้จะช่วยให้ข้อมูลพื้นฐานที่จะก้าวกระโดดขั้นตอนและป้องกันความคุ้มภัยของโรคเบาหวานได้เหมาะสม