Prevalence of Diabetes, Impaired Fasting Glucose, and Impaired Glucose Tolerance in U.S. Adults


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OBJECTIVE — To evaluate the prevalence and time trends for diagnosed and undiagnosed diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults by age, sex, and race or ethnic group, based on data from the Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III) and prior Health and Nutrition Examination Surveys (HANESs).

RESEARCH DESIGN AND METHODS — NHANES III contained a probability sample of 18,825 U.S. adults ≥20 years of age who were interviewed to ascertain a medical history of diagnosed diabetes, a subsample of 6,587 adults for whom fasting plasma glucose values were obtained, and a subsample of 2,844 adults between 40 and 74 years of age who received an oral glucose tolerance test. The Second National Health and Nutrition Examination Survey, 1976–1980, and Hispanic HANES used similar procedures to ascertain diabetes. Prevalence was calculated using the 1997 American Diabetes Association fasting plasma glucose criteria and the 1980–1985 World Health Organization (WHO) oral glucose tolerance test criteria.

RESULTS — Prevalence of diagnosed diabetes in 1988–1994 was estimated to be 5.1% for U.S. adults ≥20 years of age (10.2 million people when extrapolated to the 1997 U.S. population). Using American Diabetes Association criteria, the prevalence of undiagnosed diabetes (fasting plasma glucose ≥126 mg/dl) was 2.7% (5.4 million), and the prevalence of impaired fasting glucose (110 to <126 mg/dl) was 6.9% (13.4 million). There were similar rates of diabetes for men and women, but the rates for non-Hispanic blacks and Mexican-Americans were 1.6 and 1.9 times the rate for non-Hispanic whites. Based on American Diabetes Association criteria, prevalence of diabetes (diagnosed plus undiagnosed) in the total population of people who were 40–74 years of age increased from 8.9% in the period 1976–1980 to 12.3% by 1988–1994. A similar increase was found when WHO criteria were applied (11.4 and 14.3%).

CONCLUSIONS — The high rates of abnormal fasting and postchallenge glucose found in NHANES III, together with the increasing frequency of obesity and sedentary lifestyles in the population, make it likely that diabetes will continue to be a major health problem in the U.S.

Diabetes and its complications are a significant cause of morbidity and mortality in the U.S. The prevalence of physician-diagnosed diabetes has been steadily increasing in the U.S. population, based on national household interview surveys conducted during the past 40 years (1). Undiagnosed diabetes and abnormal glucose tolerance are also considered to have substantial clinical importance (2–5), but national estimates of their prevalence have been available from only one survey of a representative sample of U.S. adults (Second National Health and Nutrition Examination Survey, 1976–1980 [NHANES II]) (6) and one survey of a representative sample of Mexican-Americans in the southwestern U.S. (Hispanic Health and Nutrition Examination Survey [HANES], 1982–1984) (7). Furthermore, new criteria for defining diabetes based on fasting plasma glucose have been proposed by an expert committee of the American Diabetes Association (8), and adoption of these criteria may affect prevalence rates for the various diabetes diagnostic categories.

The objective of this study is to examine the prevalence and time trends for diagnosed and undiagnosed diabetes and other categories of abnormal glucose values according to age, sex, and race or ethnic group in the U.S. population. To define the diabetes diagnostic groups, both the 1997 criteria of the American Diabetes Association (8) and the 1980–1985 criteria of the World Health Organization (WHO) (9,10) are used. We present prevalence rates based on the most recent national survey, the Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III), in which medical history of diabetes and fasting and postchallenge plasma glucose were obtained for a national sample of adults, including non-Hispanic whites, non-Hispanic blacks, and Mexican-Americans. These data are compared with prevalence computed from the NHANES II and Hispanic HANES, in which similar procedures were used to ascertain presence of diabetes.
Survey design and response rates for previously diagnosed diabetes
NHANES III was conducted during 1988–1994 by the National Center for
Health Statistics of the Centers for Disease
Control and Prevention (11,12). The survey included a nationally representative
sample of the U.S. civilian noninstitutionalized population, based on a complex,
stratified, multistage probability cluster sampling design with oversampling of
blacks and Mexican-Americans. The protocol included a home interview followed
by a physical examination in a mobile examination center.

A total of 18,825 people who were ≥20 years of age (81% of all eligible sub-
jects) completed a household interview in which information was obtained about
demographic characteristics, race, Hispanic ethnicity, and medical history of diabetes.
For the last item, questions were asked about a prior diagnosis of diabetes by a
physician; women were also asked whether the diagnosis had been made during preg-
nancy and whether they had also been told after pregnancy that they had diabetes.
Based on this information, 1,503 adults were classified as having previously diag-
nosed diabetes, including 658 men and 845 women. Of the women, 47 had been
told of their diabetes during pregnancy but also had a diagnosis of diabetes made out-
side of pregnancy. Three subjects were excluded from analysis because of missing
information. The remaining 17,319 sub-
jects (8,158 men and 9,161 women) were
categorized as not having diagnosed dia-
betes, including 105 women who appeared to have only gestational diabetes.

Fasting plasma glucose and the oral
glucose tolerance test
Each household was randomly assigned to
either a morning or an afternoon/evening
examination session. There were 8,608 peo-
ples ≥20 years of age who did not have diag-
nosed diabetes and who were assigned to a
morning session, and plasma glucose values
were obtained after an overnight fast of 9 to
<24 h for 6,587 people (77%). This included 2,798 non-Hispanic whites, 1,753
non-Hispanic blacks, 1,771 Mexican-American,
and 265 people of other racial or eth-
nic groups. Plasma glucose values were not
obtained for people who did not participate
in the examination (n = 811), were exam-
inated at home where fasting was not
required (n = 209), were examined in the
afternoon/evening (n = 331), had medical
and safety reasons for exclusion (n = 10),
became faint or ill (n = 2), refused the
venipuncture (n = 28), had unsuccessful
venipuncture (n = 27), fasted for <9 h (n = 369) or >24 h (n = 8), or had an unknown
fasting time (n = 89), and for other reasons
(n = 137). For a subsample of subjects aged
40–74 years, a 75-g glucose-equivalent oral
glucose challenge (Dextol or Trutol) was
given and a blood sample was drawn 2 h
(±15 min) later. The postchallenge glucose
value was obtained for 2,844 (93%) of the
3,055 people aged 40–74 years who had no
medical history of diabetes and for whom an
overnight fasting plasma glucose value
was obtained. This group consisted of 1,390
men and 1,454 women; 1,373 of the sub-
jects were non-Hispanic whites, 690 were non-Hispanic blacks, 657 were Mexican-
Americans, and 124 were of other racial or
ethnic categories. There were no statistically
significant differences in a variety of
sociodemographic and clinical variables between
subjects assigned to the morning session versus subjects assigned to the after-
noon/evening session. In addition, for those in
the morning session, there were no
significant differences between subjects for
whom plasma glucose values were obtained
versus those for whom plasma glucose val-
ues were not obtained. Thus, data from the
subsamples are considered to represent the
entire NHANES III sample.

The procedures for blood collection and
processing have been described (12). Venous whole blood was collected into
a vacuum tube containing the glycolytic
inhibitors potassium oxalate and sodium
fluoride and was centrifuged immediately at
1500g for 10 min. The plasma was frozen at
−70°C, shipped on dry ice to the University of Missouri Diabetes Diagnostic Laboratory,
and stored at −70°C until analysis. Plasma
glucose was measured using a modified hex-
okinase enzymatic method. Both within-
assay and between-assay quality control
procedures were used; the coefficient of vari-
ation of the method was 1.6–3.7% during
the 6 years of the survey (12).

People without previously diagnosed
diabetes were categorized according to
American Diabetes Association diagnostic
criteria (8) as follows: undiagnosed dia-
betes, fasting plasma glucose ≥126 mg/dl;
impaired fasting glucose, fasting plasma glu-
cose 110 to <126 mg/dl. Using 1980–1985
WHO criteria (9,10), the diagnostic criteria
for people without diagnosed diabetes were
undiagnosed diabetes, fasting plasma glu-
cose ≥140 mg/dl or 2-h plasma glucose
≥200 mg/dl; impaired glucose tolerance,
fasting plasma glucose <140 mg/dl and 2-
hour plasma glucose 140 to <200 mg/dl.

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Data are % and are based on a medical history interview in which subjects were asked about prior diagno-
sis of diabetes by a physician. *Values are age- and sex-standardized. †Values include those of racial and eth-
nic groups not listed separately.

Table 1—Percentage of the U.S. population: 20 years of age with physician-diagnosed diabetes, based on NHANES III, 1988–1994
and from NHANES III, NHANES II, and Hispanic HANES should provide reasonably valid estimates of trends for Mexican-Americans.

Statistical analysis
Statistical analyses were carried out using SAS (15) and SUDAAN (16). To provide estimates that were representative of the U.S. population, analyses of each HANES incorporated sampling weights. These weights account for the unequal probabilities of selection resulting from the cluster design, the planned oversampling of certain demographic subgroups, and nonresponse adjustment factors based on U.S. Census Bureau data on age, sex, race, income, and geographic location of the U.S. population. Separate weights were used for the interviewed sample (subjects with diagnosed diabetes) and the plasma glucose samples (subjects with undiagnosed diabetes, impaired fasting glucose, or impaired glucose tolerance).

RESULTS — Prevalence of diabetes diagnosed by a physician before NHANES III is shown in Table 1. Prevalence was 5.1% (95% CI 4.7–5.6) for all people ≥20 years of age, 5.0% (4.4–5.6) for non-Hispanic whites, 6.9% (6.2–7.7) for non-Hispanic blacks, and 5.6% (5.1–6.2) for Mexican-Americans. Prevalence rates increased with age, although there was a slight decline at age ≥75 years for non-Hispanic blacks and Mexican-Americans. Rates were similar in men and women for non-Hispanic whites but were higher in women for non-Hispanic blacks and Mexican-Americans: the ratio of the age-standardized rate in women vs. men was 0.87 for non-Hispanic whites (NS), 1.25 for non-Hispanic blacks, and 1.41 for Mexican-Americans (P = 0.04), 1.41 for Mexican-Americans (P = 0.003), and 0.98 for all races combined (NS). Prevalence was lower in non-Hispanic whites: the age- and sex-standardized prevalence ratio for non-Hispanic whites vs. non-Hispanic blacks was 1.70 (P < 0.0001) and vs. Mexican-Americans was 1.92 (P < 0.0001). The difference between non-Hispanic blacks and Mexican-Americans was not statistically significant.

When the rates in Table 1 were applied to U.S. population projections for 1997, the number of people ≥20 years of age who have diagnosed diabetes was estimated to be 7.5 million for non-Hispanic whites, 1.5 million for non-Hispanic blacks, and 4.8 million for Mexican-Americans.
million for non-Hispanic blacks, 0.8 million for Mexican-Americans, 4.6 million for men, 5.6 million for women, and 10.2 million for the total population.

The prevalence of undiagnosed diabetes using American Diabetes Association fasting plasma glucose criteria is shown in Table 2. Prevalence increased with age, although for some race/sex groups, there was a decline in the rate for those 75 years of age. The age-standardized prevalence was slightly higher in men than in women for non-Hispanic whites and Mexican-Americans, but was lower in men than in women for non-Hispanic blacks. The age- and sex-standardized rate for non-Hispanic whites (2.5%) was somewhat lower than for non-Hispanic blacks (3.6%) and Mexican-Americans (4.5%). When the rates in Table 2 were applied to U.S. population projections for 1997, the number of people ≥20 years of age who have diabetes (either diagnosed or undiagnosed) was estimated to be 7.5 million for men, 8.1 million for women, 11.3 million for non-Hispanic whites, 2.3 million for non-Hispanic blacks, 1.2 million for Mexican-Americans, and 15.6 million for the total population.

The prevalence of impaired fasting glucose is shown in Table 2. Rates increased from age 20–39 years to age 60–74 years or age ≥75 years. Prevalence was higher for men than for women in each racial or ethnic group, and the ratio of the age-standardized rate in men vs. women was 1.8 for all races combined. The age- and sex-standardized prevalence for Mexican-Americans (8.9%) was somewhat higher than the rates for non-Hispanic whites (6.8%) and non-Hispanic blacks (7.0%). When the rates in Table 2 were applied to U.S. population projections for 1997, the numbers of people ≥20 years of age who have impaired fasting glucose were estimated to be 10.3 million for non-Hispanic whites, 1.3 million for non-Hispanic blacks, 0.9 million for Mexican-Americans, 8.1 million for men, 5.3 million for women, and 13.4 million for the total population.

Figure 2 compares prevalence in non-Hispanic whites, non-Hispanic blacks, and...
Table 3—Percentage of the U.S. population 40–74 years of age with undiagnosed diabetes and impaired glucose tolerance, based on 1980–1985 World Health Organization fasting and postchallenge plasma glucose diagnostic criteria and NHANES III (1988–1994)

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Data are %. Undiagnosed diabetes is defined as fasting plasma glucose ≥140 mg/dl or 2-h postchallenge glucose ≥200 mg/dl; impaired glucose tolerance is defined as fasting plasma glucose <140 mg/dl and 2-h glucose 140–199 mg/dl. *Values are age- and sex-standardized. †Values include those of racial and ethnic groups not listed separately.

CONCLUSIONS — Data from these national surveys document that diabetes is a major health problem in both men and women and in the three main racial and ethnic groups in the U.S. Whereas the prevalence of hypertension (20) and hypercholesterolemia (21), and the incidence of and mortality from heart disease (22,23) and stroke (24), are markedly declining in the U.S., the prevalence of diabetes remains high. Diabetes has become one of the most common chronic diseases in our country. Using American Diabetes Association criteria, the NHANES III data indicate that diabetes (diagnosed and undiagnosed combined) affects 7.8% of adults ≥20 years of age in the U.S., with rates reaching 18.8% at ≥60 years of age. U.S. minorities are more Mexican-Americans. Within each racial or ethnic group, the proportion with diabetes was similar for men and women. Diabetes was more common in non-Hispanic blacks and Mexican-Americans: the ratio of the age- and sex-standardized prevalence vs. non-Hispanic whites was 1.6 and 1.9, respectively. The sum of the age- and sex-standardized rates of diabetes plus impaired fasting glucose was also higher for non-Hispanic blacks (18.8%) and Mexican-Americans (22.7%) than for non-Hispanic whites (14.1%).

Total prevalence of diabetes and impaired fasting glucose combined, using American Diabetes Association criteria, is estimated to be 21.6 million for non-Hispanic whites, 3.6 million for non-Hispanic blacks, 2.1 million for Mexican-Americans, 15.6 million for men, 13.4 million for women, and 29.0 million for the total population.

The prevalence of undiagnosed diabetes using 1980–1985 WHO criteria is shown in Table 3 for people 40–74 years of age. The prevalence rates increased with age except for a decline at 60–74 years of age for non-Hispanic blacks and Mexican-Americans. Rates were somewhat greater for men than for women in each racial or ethnic group. The age- and sex-standardized prevalence rate was higher in Mexican-Americans (11.4%) than non-Hispanic whites (6.4%) and non-Hispanic blacks (7.5%). The prevalence of impaired glucose tolerance (Table 3) increased with age for almost all sex and racial or ethnic groups. The rates were similar for men and women in each racial or ethnic group, and the age- and sex-standardized rate was higher for Mexican-Americans (20.2%) than for non-Hispanic whites (15.3%) and non-Hispanic blacks (14.0%).
frequently affected by diabetes, and the risk of diabetes for Mexican-Americans and non-Hispanic blacks in NHANES III is almost twice that for non-Hispanic whites. The prognostic significance of impaired fasting glucose, which is found in 6.9% of those ≥20 years of age, has yet to be defined but is likely to be a strong risk factor for development of clinical diabetes. Impaired glucose tolerance, defined by the oral glucose tolerance test, is a known risk factor for diabetes and for heart disease and occurs in 15.6% of adults 40–74 years of age.

The lower prevalence of undiagnosed diabetes using American Diabetes Association criteria compared with prevalence using WHO criteria is found because 48% of individuals with postchallange glucose ≥200 mg/dl have fasting plasma glucose <126 mg/dl (25). The lower prevalence of impaired fasting glucose compared with impaired glucose tolerance is found because 70% of individuals with 2-h plasma glucose...
140 to <200 mg/dl have fasting plasma glucose <110 mg/dl (25). Rates of undiagnosed diabetes and impaired fasting glucose using American Diabetes Association criteria, which are defined by the fasting plasma glucose value, are higher in men than in women. This phenomenon is due to the higher fasting plasma glucose values for men in the U.S. population as a whole: the mean fasting plasma glucose for those without previously diagnosed diabetes is 100 mg/dl for men vs. 95 mg/dl for women in NHANES III. In contrast, mean 2-h glucose values are 120 mg/dl and 123 mg/dl, respectively.

Many factors influence the prevalence of diabetes, including those that affect the development of new cases of diabetes and those that affect mortality from diabetes. Examination of these factors is beyond the scope of this manuscript, but data from the HANESs indicate that increases in the prevalence of diabetes have occurred over time. Evaluation of this trend should be tempered by the facts that 1) there are only two time points for each racial or ethnic group and 2) there were different survey personnel, response rates, and laboratories for glucose analysis in these surveys. The annual National Health Interview Survey, which involves a household interview to ascertain physician-diagnosed diabetes, also shows increases in diabetes prevalence over time (1). This survey shows a relatively stable incidence rate for diabetes during 1970–1992 (about 2.7 new diagnoses per 1,000 population per year), and declines in mortality of people with diabetes may account for the growing prevalence rates.

The HANESs have shown a substantial increase in the prevalence in the U.S. of obesity (26), which is a major risk factor for diabetes. This increase, together with the high frequency of sedentary lifestyles in the U.S. (27) and the high rates of impaired fasting glucose and impaired glucose tolerance found in NHANES III, portends that diabetes will continue to have a major impact on the health of the U.S. population.

References