Prevalence of Diabetes and Impaired Fasting Glucose in Adults in the U.S. Population

National Health and Nutrition Examination Survey 1999–2002

CATHERINE C. COWIE, PHD[1]
KEITH F. RUST, PHD[2]
DANITA D. BYRD-HOLT, BBA[3]
MARK S. EBERHARDT, PHD[4]
KATHERINE M. FLEGAL, PHD[4]

MICHAEL M. ENGELGAU, MD[5]
SHARON H. SAYDAH, PHD[4]
DESMOND E. WILLIAMS, MD[5]
LINDA S. GEISS, MS[5]
EDWARD W. GREGG, PHD[5]

OBJECTIVE — The purpose of this study was to examine the prevalences of diagnosed and undiagnosed diabetes, and impaired fasting glucose (IFG) in U.S. adults during 1999–2002, and compare prevalences to those in 1988–1994.

RESEARCH DESIGN AND METHODS — The National Health and Nutrition Examination Survey (NHANES) contains a probability sample of adults aged ≥20 years. In the NHANES 1999–2002, 4,761 adults were classified on glycemic status using standard criteria, based on an interview for diagnosed diabetes and fasting plasma glucose measured in a subsample.

RESULTS — The crude prevalence of total diabetes in 1999–2002 was 9.3% (19.3 million, 2002 U.S. population), consisting of 6.5% diagnosed and 2.8% undiagnosed. An additional 26.0% had IFG, totaling 35.3% (73.3 million) with either diabetes or IFG. The prevalence of total diabetes rose with age, reaching 21.6% for those aged ≥65 years. The prevalence of diagnosed diabetes was twice as high in non-Hispanic blacks and Mexican Americans compared with non-Hispanic whites (both $P < 0.00001$), whereas the prevalence of undiagnosed diabetes was similar by race/ethnicity, adjusted for age and sex. The prevalence of diagnosed diabetes was similar by sex, but prevalences of undiagnosed diabetes and IFG were significantly higher in men. The crude prevalence of diagnosed diabetes rose significantly from 5.1% in 1988–1994 to 6.5% in 1999–2002, but the crude prevalences were stable for undiagnosed diabetes (from 2.7 to 2.8%) and IFG (from 24.7 to 26.0%). Results were similar after adjustment for age and sex.

CONCLUSIONS — Although the prevalence of diagnosed diabetes has increased significantly over the last decade, the prevalences of undiagnosed diabetes and IFG have remained relatively stable. Minority groups remain disproportionately affected.

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D iabetes and its complications are major causes of morbidity and mortality in the U.S. (1). The economic cost of diabetes in medical expenditures and lost productivity was estimated to be $132 billion in the U.S. in 2002 (2). Nationally the prevalence of self-reported diagnosed diabetes has steadily increased over time (3), but the extent to which this increase is due to enhanced detection is uncertain. Undiagnosed diabetes and impaired fasting glucose (IFG) also have important health consequences (4,5). Only one nationally representative survey, The National Health and Nutrition Examination Survey (NHANES), examines both diagnosed diabetes and undiagnosed diabetes. This survey showed that from 1988 to 1994, undiagnosed diabetes comprised approximately one-third of total diabetes (diagnosed and undiagnosed) in U.S. adults (6). The prevalence of IFG was nearly as high as the prevalence of total diabetes. In 1999, the NHANES became a continuous annual survey with data released every 2 years, and we reported the prevalence of diagnosed diabetes, undiagnosed diabetes, and IFG in adults based on data from 1999 to 2000 (7). The limited sample size in these 2 years, however, restricted the detail and reliability of our analyses. New criteria for defining IFG have since been adopted (8,9), and only limited estimates of the prevalence of IFG based on this new definition have been reported using the 2 years of data from NHANES 1999 to 2000 (10).

In this report, we analyze the prevalence of diagnosed diabetes, undiagnosed diabetes, and IFG in adults in the U.S. using 4 years of the NHANES data (1999–2002). Results are examined in detail according to age, sex, and race/ethnicity. We compare these prevalence estimates to those from the NHANES 1988–1994.

RESEARCH DESIGN AND METHODS

— The NHANES 1999–2002 was conducted by the National Center for Health Statistics (11). The survey is designed to be representative of the U.S. civilian noninstitutionalized population, on the basis of a complex, multistage probability sample. Survey participants are interviewed in their homes and subsequently receive a physical and laboratory examination in a mobile examination center. Among eli-

gible subjects, 83.0% were interviewed and 78.0% were examined.

In 1999–2002, 10,291 individuals aged ≥20 years completed the household interview. Questions covered demographic characteristics and medical conditions, including a history of diabetes. Specifically, individuals were asked if, other than during pregnancy for women, a doctor or health care professional had ever told them they had diabetes. Based on this question, 991 individuals aged ≥20 years were classified as having diagnosed diabetes. Three additional individuals were excluded from analyses because of missing diabetes information.

Each household was randomly assigned to either a morning or afternoon/evening examination session. There were 4,271 individuals aged ≥20 years without diagnosed diabetes who were assigned to a morning session, and plasma glucose values were obtained from 3,770 (88.3%) of them after they fasted for 8 to <24 h. This group is subsequently referred to as the plasma glucose subsample. Recommendations for the diagnosis of diabetes are based on studies of plasma glucose measured after an overnight fast (9). Pregnant women ($n = 236$) were included, and none had undiagnosed diabetes based on their fasting plasma glucose (FPG) values. Plasma glucose values were not analyzed for 420 people with invalid or unknown fasting times and 81 people with unknown glucose values.

The procedures for blood collection and processing are described elsewhere (11). Plasma glucose was measured at a central laboratory using a hexokinase enzymatic method, with a coefficient of variation of <3% during the 4 years of the survey. Standard diagnostic criteria were used to categorize people without diagnosed diabetes as to whether they had undiagnosed diabetes (FPG ≥7.0 mmol/l) or IFG (FPG 5.6 to <7.0 mmol/l) (9). Race/ethnicity was categorized according to NHANES guidelines to allow comparison across the surveys (11). Age was categorized as ≥60 years for consistency with NHANES guidelines (11) and ≥65 years to provide findings relevant to the Medicare population.

Estimates from the NHANES 1999–2002 are compared with those from the NHANES III conducted during 1988–1994. The NHANES III used similar interview questions on previous diagnosis of diabetes (6,11). The same collection methods and laboratory were used for all specimens to determine FPG concentration (11).

Sampling weights were used to provide estimates that are representative of the U.S. population (11). For the NHANES 1999–2002, individuals with diagnosed diabetes from the entire interviewed sample were combined with individuals without diagnosed diabetes from the plasma glucose subsample. Appropriate sampling weights were used so that the sum of the sample weights from the two groups added to the total U.S. population. For the NHANES 1988–1994, prevalences of normal fasting glucose, undiagnosed diabetes, and IFG in the subsample of people without diagnosed diabetes were each adjusted for the prevalence of diagnosed diabetes from the interview sample, so that the sum of all diagnostic categories added to the total U.S. population (12). This difference in approach for NHANES 1988–1994 was required because the plasma glucose subsample weights for that survey did not account for some individuals having invalid or unknown fasting times or unknown plasma glucose values.

To account for different age and sex distributions between groups and over time, we derived estimates that were age- and sex-standardized to the U.S. 2000 Census population using the direct method, with age categories of 20–39, 40–59, and ≥60 years. SUDAAN (13) was used to calculate SEs in the NHANES 1999–2002 based on the Taylor Series linearization method (14). For the NHANES 1988–1994, variance estimates were based on Fay's modified balanced repeated replication (15), an alternative method that is preferred for the data provided in the NHANES 1988–1994. A SAS routine was written specifically for these analyses.

CIs were calculated for the logit of each estimated percentage, and then the end points were back-transformed (16). A one-sample t test was used for testing whether differences between subgroups in proportions in the NHANES 1999–2002 were significantly different from zero. Two-sample t tests were used to test differences in proportions between the two surveys. A P value of ≤0.05 was considered statistically significant. When we compared estimates among subgroups or within subgroups over time, no adjustments were made for multiple comparisons in determining the statistical significance of differences.

RESULTS

Diagnosed diabetes
The prevalence of diagnosed diabetes ascertained by interview in adults aged ≥20 years in 1999–2002 is shown in Table 1. Overall the crude prevalence was 6.5% for the total population, 5.6% in non-Hispanic whites, 10.0% in non-Hispanic blacks, and 6.5% in Mexican Americans. The prevalence generally rose with age in all race/ethnic groups and sex-groups, reaching 15.8% at ages ≥65 years for the total population. The overall crude prevalence was similar for men (6.7%) and women (6.3%).

Standardized prevalence estimates are presented in the last column of Table 1. Consistent with the age-specific prevalences, the age and sex standardized prevalence of diagnosed diabetes was about twice as high in non-Hispanic blacks (11.0%) and Mexican Americans (10.4%) compared with non-Hispanic whites (5.2%, both $P <$ 0.00001). Among non-Hispanic whites, the standardized prevalences of 6.0% in men and 4.5% in women were significantly different ($P = 0.02$), consistent with the higher prevalence in men across all ages until age ≥65 years. Among non-Hispanic blacks and Mexican Americans, however, prevalence estimates standardized by age were not significantly different between men and women.

Undiagnosed diabetes
The crude prevalence of undiagnosed diabetes ascertained by measurement of FPG in the NHANES 1999–2002 was 2.8% in the total population aged ≥20 years (Table 2). The prevalence of undiagnosed diabetes generally rose with age in all race/ethnic groups and sex-groups, reaching 5.8% overall in those aged ≥65 years. Although the crude percentage of individuals with undiagnosed diabetes was significantly lower in Mexican Americans than in non-Hispanic whites (1.8 vs. 2.9%, $P = 0.03$) and non-Hispanic blacks (1.8 vs. 3.3%, $P = 0.04$), standardized prevalences were similar for non-Hispanic whites, non-Hispanic blacks, and Mexican Americans. The standardized prevalence of undiagnosed diabetes was significantly higher in men than in women in the total population (3.6 vs 2.1%, $P = 0.02$) and in non-Hispanic whites (3.5 vs. 1.9%, $P = 0.02$), consistent with the higher prevalence in men across all ages in these groups. The standardized prevalence of undiagnosed diabetes, however, was not different by

Table 1—*Crude and standardized prevalence of diagnosed diabetes in adults aged ≥20 years in the U.S. population, NHANES 1999–2002*

	Age (years)					
	≥20	20–39	40–59	≥60	≥65	≥20, standardized*
Total population	6.5 (6.0–7.1)	1.7 (1.2–2.3)	6.6 (5.6–7.7)	15.1 (13.5–16.8)	15.8 (14.0–17.8)	6.5 (5.9–7.2)
Men	6.7 (6.0–7.5)	1.4 (0.8–2.4)	7.5 (6.4–8.8)	16.0 (13.4–19.0)	15.8 (13.1–18.8)	7.0 (6.1–7.9)
Women	6.3 (5.6–7.2)	1.9 (1.3–2.8)	5.7 (4.4–7.2)	14.4 (12.6–16.4)	15.9 (13.8–18.2)	6.1 (5.4–7.0)
Non-Hispanic whites	5.6 (5.0–6.2)	1.2 (0.8–1.9)	4.6 (3.6–5.8)	13.3 (11.6–15.2)	14.3 (12.3–16.5)	5.2 (4.6–5.8)
Men	6.1 (5.2–7.2)	1.6 (0.9–2.9)	5.5 (4.1–7.3)	14.5 (11.8–17.8)	14.3 (11.5–17.7)	6.0 (5.0–7.2)
Women	5.0 (4.4–5.7)	0.8 (0.5–1.4)	3.7 (2.7–5.1)	12.3 (10.4–14.6)	14.3 (12.0–16.9)	4.5 (4.0–5.1)
Non-Hispanic blacks	10.0 (8.5–11.8)	2.9 (1.8–4.7)	11.3 (9.0–14.1)	25.3 (20.9–30.4)	28.5 (22.8–34.9)	11.0 (9.5–12.7)
Men	8.2 (6.4–10.6)	0.7 (0.2–3.3)	9.6 (6.3–14.5)	26.3 (21.1–32.2)	29.2 (21.5–38.2)	9.8 (8.1–11.9)
Women	11.4 (9.3–13.9)	4.7 (3.1–7.0)	12.7 (9.7–16.4)	24.7 (19.4–30.9)	28.0 (21.6–35.5)	12.2 (10.0–14.7)
Mexican Americans	6.5 (5.4–7.8)	1.3 (0.8–2.1)	11.5 (9.1–14.4)	25.0 (22.1–28.1)	24.9 (22.0–28.0)	10.4 (9.3–11.7)
Men	5.4 (3.9–7.2)	0.2 (0.0–1.3)	11.0 (7.7–15.4)	25.6 (21.5–30.1)	25.6 (20.3–31.8)	9.9 (8.1–12.1)
Women	7.8 (6.2–9.7)	2.6 (1.4–4.5)	12.0 (8.6–16.5)	24.5 (19.7–30.1)	24.3 (19.0–30.6)	11.0 (9.4–12.9)

Data are % (95% CI). Values for the total population and for men and women include those of race/ethnic groups not listed separately. All CIs were logit transformed. *Standardized to the 2000 U.S. Census population by age and sex for the total population and race/ethnic groups and by age for sex-groups.

sex in non-Hispanic blacks and Mexican Americans.

IFG
The crude proportion of adults aged ≥20 years with IFG was 26.0% in 1999–2002 (Table 3). The prevalence of IFG generally increased with age in all groups, peaking at 39.1% in the total population aged ≥65 years. In Mexican-American men, however, the prevalence of IFG appeared to peak at middle ages (53.5% at age 40–59 years), although these estimates are less reliable because of the limited sample size. Standardized prevalences were similar to crude estimates. Prevalences differed considerably by race/ethnicity. The overall standardized prevalence in non-Hispanic blacks

(17.7%) was significantly lower than that in non-Hispanic whites (26.1%, $P = 0.0007$) and Mexican Americans (31.6%, $P < 0.00001$), a pattern consistent across all ages. Overall standardized prevalence was lower in non-Hispanic whites than in Mexican Americans ($P = 0.008$). The standardized prevalence was significantly higher in men (32.8%) than in women (19.5%) in the total population ($P < 0.00001$) and in non-Hispanic whites (33.1 vs. 19.6%, $P < 0.00001$) and Mexican Americans (42.2 vs. 21.2%, $P < 0.00001$).

Change in prevalences of diabetes and IFG
Table 4 shows a comparison of the prevalence of diagnosed diabetes, undiag-

nosed diabetes, total diabetes (combining diagnosed and undiagnosed), IFG, and combined total diabetes and IFG in adults aged ≥20 years during 1999–2002 and 1988–1994. Both crude and standardized prevalences are shown. The overall crude prevalence of diagnosed diabetes rose significantly from 5.1% in 1988–1994 to 6.5% in 1999–2002 ($P = 0.0002$). The significant increase was not merely attributable to changes in the age and sex distribution between the surveys since the standardized prevalence also rose significantly (from 5.4 to 6.5%, $P = 0.004$). The prevalence of diagnosed diabetes increased in all age-groups, sex-groups, and race/ethnic groups, but the increase was most prominent in older

Table 2—*Crude and standardized prevalence of undiagnosed diabetes in adults aged ≥20 years in the U.S. population, 1999–2002*

	Age (years)					
	≥20	20–39	40–59	≥60	≥65	≥ 20, standardized*
Total population	2.8 (2.3–3.5)	0.7 (0.3–1.8)	3.3 (2.2–4.8)	5.8 (4.5–7.5)	5.8 (4.1–8.0)	2.8 (2.3–3.4)
Men	3.5 (2.7–4.6)	0.4 (0.1–1.7)	5.0 (3.3–7.4)	7.0 (5.1–9.5)	7.9 (5.5–11.2)	3.6 (2.7–4.7)
Women	2.2 (1.6–2.9)	1.0 (0.3–3.2)	1.7 (0.8–3.4)	4.9 (3.4–6.8)	4.2 (2.5–6.9)	2.1 (1.6–2.8)
Non-Hispanic whites	2.9 (2.2–3.7)	0.4 (0.1–3.1)	3.3 (2.0–5.4)	5.6 (4.0–7.8)	6.0 (4.1–8.6)	2.7 (2.0–3.5)
Men	3.7 (2.7–5.2)	0.0†	5.4 (3.2–8.9)	6.8 (4.6–9.8)	8.3 (5.6–12.0)	3.5 (2.5–4.9)
Women	2.1 (1.5–2.9)	0.8 (0.1–5.7)	1.3 (0.4–4.0)	4.7 (3.0–7.5)	4.2 (2.3–7.7)	1.9 (1.3–2.8)
Non-Hispanic blacks	3.3 (2.2–5.0)	1.5 (0.5–4.1)	3.5 (1.5–7.7)	7.8 (4.6–13.0)	7.2 (3.6–13.9)	3.6 (2.5–5.2)
Men	2.7 (1.5–4.9)	1.2 (0.3–4.8)	2.2 (0.6–7.4)	8.1 (3.0–20.1)	7.6 (2.6–20.3)	3.2 (1.7–5.9)
Women	3.8 (2.4–6.1)	1.7 (0.4–6.7)	4.5 (1.8–10.4)	7.6 (3.9–14.4)	6.9 (2.8–16.3)	4.1 (2.6–6.3)
Mexican Americans	1.8 (1.3–2.6)	0.0†	3.8 (2.2–6.6)	7.3 (4.4–11.9)	7.8 (3.8–15.2)	3.0 (2.1–4.3)
Men	2.4 (1.5–3.9)	0.0†	6.5 (3.6–11.4)	6.8 (3.6–12.4)	8.0 (3.4–17.9)	3.9 (2.6–5.9)
Women	1.2 (0.6–2.3)	0.0†	1.0 (0.2–4.2)	7.7 (3.6–16.1)	7.6 (2.5–20.4)	2.1 (1.0–4.4)

Data are % (95% CI). Undiagnosed diabetes is defined as fasting plasma glucose ≥7.0 mmol/l. Values for the total population and for men and women include those of race/ethnic groups not listed separately. All CIs were logit transformed. *Standardized to the 2000 U.S. Census population by age and sex for the total population and race/ethnic groups and by age for sex-groups. †In the age 20- to 39-year group, there was no undiagnosed diabetes among 256 non-Hispanic white men and 400 Mexican Americans (186 men and 214 women) who were in the nondiabetic fasting morning sample.

Table 3—Crude and standardized prevalence of IFG in adults age ≥20 years in the U.S. population, 1999–2002

	Age (years)					
	≥20	20–39	40–59	≥60	≥65	≥20, standardized*
Total population	26.0 (23.7–28.5)	15.9 (13.4–18.8)	29.9 (26.6–33.4)	37.5 (34.2–40.9)	39.1 (35.5–42.9)	26.0 (23.8–28.4)
Men	32.6 (29.4–36.1)	23.9 (19.5–28.8)	37.2 (32.6–42.1)	41.8 (36.2–47.6)	43.2 (37.2–49.4)	32.8 (29.8–36.0)
Women	20.0 (17.9–22.2)	8.2 (6.0–11.1)	22.9 (19.8–26.3)	34.2 (30.2–38.5)	36.0 (32.0–40.2)	19.5 (17.5–21.7)
Non-Hispanic whites	27.0 (24.1–30.2)	15.3 (11.9–19.3)	30.2 (25.8–35.1)	38.8 (34.4–42.3)	40.0 (36.2–43.9)	26.1 (23.4–29.1)
Men	33.7 (29.6–38.0)	22.6 (16.9–29.5)	37.8 (31.7–44.3)	44.1 (37.7–50.7)	45.0 (38.5–51.7)	33.1 (29.3–37.1)
Women	20.9 (18.3–23.8)	8.2 (5.2–12.7)	22.8 (18.5–27.8)	34.7 (30.0–39.6)	36.2 (31.8–40.9)	19.6 (17.1–22.4)
Non-Hispanic blacks	16.8 (13.9–20.1)	9.5 (5.9–15.0)	21.3 (15.8–28.2)	25.5 (20.0–31.9)	24.5 (17.9–32.5)	17.7 (14.8–21.0)
Men	19.2 (15.3–23.8)	10.9 (6.1–18.6)	26.9 (19.7–35.5)	23.9 (15.0–35.8)	23.0 (13.6–36.2)	19.7 (15.9–24.2)
Women	14.9 (11.3–19.3)	8.4 (4.5–15.3)	16.7 (10.2–26.2)	26.6 (19.7–34.7)	25.6 (18.8–33.8)	15.6 (11.9–20.2)
Mexican Americans	30.1 (26.7–33.8)	25.2 (20.5–30.6)	40.1 (35.4–44.9)	32.1 (27.1–37.6)	34.3 (27.8–41.6)	31.6 (28.8–34.5)
Men	41.1 (37.6–44.7)	36.5 (31.5–41.9)	53.5 (46.7–60.1)	34.3 (28.3–40.8)	31.9 (24.4–40.6)	42.2 (39.0–45.5)
Women	18.0 (14.0–23.0)	12.0 (7.2–19.1)	25.7 (20.3–32.1)	30.4 (22.2–40.0)	36.1 (25.3–48.5)	21.2 (17.4–25.5)

Data are % (95% CI). IFG is defined as fasting plasma glucose 5.6–7.0 mmol/l. Values for the total population and for men and women include those of race/ethnic groups not listed separately. All CIs were logit transformed. *Standardized to the 2000 U.S. Census population by age and sex for the total population and race/ethnic groups and by age for sex-groups.

ages (standardized prevalence from 12.7 to 15.2% in age ≥60 years, P = 0.02, and from 12.8 to 15.8% in age ≥65 years, P = 0.01), in men (standardized prevalence from 5.3 to 7.0%, P = 0.002), and in non-Hispanic blacks (standardized prevalence from 8.4 to 11.0%, P = 0.007). In contrast, the prevalence of undiagnosed diabetes was stable across the two surveys, overall (standardized prevalence 2.8% in both 1988–1994 and 1999–2002) and in most subgroups; one exception was in Mexican Americans in whom there was a significant decrease in the crude prevalence, but no significant change in the standardized prevalence. The overall total crude prevalence of diabetes (diagnosed and undiagnosed) increased from 7.8% in 1988–1994 to 9.3% in 1999–2002 (P = 0.007), but the change in standardized prevalence was less and not statistically significant (from 8.2 to 9.3%, P = 0.06). The change in standardized prevalence was most prominent in men (from 8.7 to 10.6%, P = 0.02) and in non-Hispanic blacks (from 12.3 to 14.6%, P = 0.04). The standardized prevalence of IFG was stable across the two surveys in all groups (overall from 25.5 to 26.0%) except for non-Hispanic blacks in whom there was a decrease (from 23.3 to 17.7%, P = 0.005). The combined prevalence of diabetes (diagnosed and undiagnosed) and IFG was also constant across the two surveys, overall (standardized prevalence from 33.7 to 35.3%) and in all subgroups.

Ratio of undiagnosed to total diabetes
In 1999–2002, the percentage of total diabetes that was undiagnosed, based on the ratio of the crude prevalence of undiagnosed and total diabetes, was 30.1% [95% CI 25.8–34.9] (results in this section are not tabulated). Although this percentage was lower than that in 1988–1994 (34.6% [30.6–38.9]) because of the significant increase in diagnosed diabetes and stable prevalences of undiagnosed diabetes across the two surveys, the change was not significant (P = 0.15), nor was there a significant change in the standardized percentage of total diabetes that was undiagnosed between the two surveys (34.5% in 1988–1994, 30.1% in 1999–2002, P = 0.16). The decreases between the surveys in the standardized percentage of total diabetes that was undiagnosed for non-Hispanic blacks (from 31.5 to 24.8%) and Mexican Americans (from 31.5 to 22.4%) were not significant. In 1999–2002, the percentage of diabetes that was undiagnosed was significantly higher in non-Hispanic whites (34.0% [95% CI 28.2–39.7]) than in Mexican Americans (21.8% [14.4–29.2], P = 0.01) and in men (34.3% [27.8–40.9]) than in women (25.5% [19.9–31.1], P = 0.05). There were no significant differences, however, by age. Similar results were found using standardized prevalences.

CONCLUSIONS — Diabetes affects a substantial proportion of the U.S. population. Based on data from the NHANES 1999–2002, 9.3% of persons aged ≥20 years had either diagnosed or undiagnosed diabetes, representing an estimated 19.3 million persons in 2002. This percentage rose to 21.6% in those aged ≥65 years. About one-third (30.1%) of diabetes was undiagnosed. An additional 26.0% of adults had IFG, a condition that increases the risk for diabetes and is associated with other cardiovascular risk factors (5). Thus, a combined total of 35.3% of the adult U.S. population (73.3 million persons) had diabetes or IFG. The prevalence of diagnosed diabetes has increased significantly from 1988–1994 to 1999–2002, yet prevalences of undiagnosed diabetes and IFG have remained relatively stable. Considerable variation by race/ethnicity and sex in the prevalences of diabetes and IFG continues to exist, once adjustments are made for differing age/sex distributions.

Our point estimates, which are based on 4 years of data, are more precise than the preliminary estimates, which were previously reported based on 2 years of data (7,10). Nevertheless, some of the estimates we report here for subgroups defined simultaneously by age, sex, and race/ethnicity are unreliable, particularly for the prevalence of undiagnosed diabetes. CI have been provided, however, to assist reader interpretation.

The FPG value is currently recommended for screening for diabetes and IFG because it is quick, easy to obtain, and acceptable to patients in clinical settings. Oral glucose tolerance tests were not performed in the NHANES 1999–2002; consequently, additional individuals with abnormal postload glucose tolerance and normal fasting glucose levels have not been identified. Although this group is unlikely to affect prevalence of diabetes substantially (8), the addition of impaired glucose tolerance (IGT) would significantly increase estimates of total pre-diabetes (IFG and IGT) (5–6,17). It

Table 4—*Prevalence of diabetes and IFG in adults aged ≥20 years in the U.S. population, NHANES 1988–1994 and 1999–2002*

| | Total population | Age (years) | | | | Men | Women | Non-Hispanic whites | Non-Hispanic blacks | Mexican Americans |
		20–39	40–59	≥60	≥65					
Diagnosed diabetes										
Crude percent										
1988–1994	5.1	1.1	5.5	12.8	12.9	4.9	5.4	5.0	6.9	5.6
1999–2002	6.5*	1.7	6.6	15.1†	15.8†	6.7*	6.3	5.6	10.0*	6.5
Standardized percentage‡										
1988–1994	5.4	1.1	5.5	12.7	12.8	5.3	5.4	4.9	8.4	9.6
1999–2002	6.5*	1.7	6.6	15.2†	15.8†	7.0*	6.1	5.2	11.0*	10.4
Undiagnosed diabetes										
Crude percent										
1988–1994	2.7	0.6	3.3	6.1	5.6	3.0	2.4	2.5	3.4	3.4
1999–2002	2.8	0.7	3.3	5.8	5.8	3.5	2.2	2.9	3.3	1.8*
Standardized percentage‡										
1988–1994	2.8	0.6	3.3	6.3	5.8	3.3	2.5	2.5	3.9	4.4
1999–2002	2.8	0.7	3.3	5.9	6.0	3.6	2.1	2.7	3.6	3.0
Total diabetes										
Crude percent										
1988–1994	7.8	1.6	8.8	18.9	18.4	7.9	7.8	7.5	10.4	9.0
1999–2002	9.3†	2.3	9.8	20.9	21.6	10.2*	8.5	8.4	13.3†	8.3
Standardized percentage‡										
1988–1994	8.2	1.6	8.8	19.0	18.6	8.7	7.8	7.4	12.3	14.0
1999–2002	9.3	2.4	9.8	21.1	21.8	10.6†	8.2	7.8	14.6†	13.5
IFG										
Crude percent										
1988–1994	24.7	14.8	29.6	37.2	37.7	32.1	18.0	24.8	20.8	26.5
1999–2002	26.0	15.9	29.9	37.5	39.1	32.6	20.0	27.0	16.8†	30.1
Standardized percentage‡										
1988–1994	25.5	14.7	29.6	37.9	38.6	33.2	18.2	25.1	23.3	31.2
1999–2002	26.0	15.7	29.8	37.9	39.5	32.8	19.5	26.1	17.7*	31.6
Combined total diabetes and IFG										
Crude percent										
1988–1994	32.5	16.4	38.5	56.1	56.1	40.0	25.8	32.2	31.1	35.5
1999–2002	35.3	18.3	39.7	58.4	60.7	42.9	28.5	35.4	30.1	38.4
Standardized percentage‡										
1988–1994	33.7	16.3	38.5	56.9	57.2	41.9	26.1	32.5	35.6	45.3
1999–2002	35.3	18.1	39.6	58.9	61.3	43.4	27.7	34.0	32.3	45.1

Undiagnosed diabetes is defined as FPG ≥7.0 mmol/l. IFG is defined as FPG 5.6 to <7.0 mmol/l. Values for the total population, by age, and by sex include those of race/ethnic groups not listed separately. *$P < 0.01$ between surveys. †$P < 0.05$ between surveys. ‡Standardized to the 2000 U.S. Census population by age and sex for the total population and race/ethnic groups, by sex for age-groups, and by age for sex-groups.

should also be noted that determination of undiagnosed diabetes and IFG in the NHANES was based on a single plasma glucose reading from subjects who self-reported that they fasted appropriately; this result may not be duplicated upon retesting as suggested for diagnosis in a clinical setting. Consequently, some of the prevalence estimates may be overstated. There are no better surveys, however, for a national assessment of diabetes and pre-diabetes using current diagnostic criteria.

Although the increase in total diabetes over the last decade was not statistically significant, the prevalence did rise significantly in men and in non-Hispanic blacks. Overweight and obesity have also risen over the last decade (18). Available data are not sufficient to investigate whether this association might be causal.

Currently, non-Hispanic blacks and Mexican Americans have almost twice the standardized prevalence of total diabetes of non-Hispanic whites, and no evidence indicates that this differential has declined over the last decade. Clearly, however, the proportion of total diabetes that is undiagnosed is no greater in non-Hispanic blacks and Mexican Americans than in non-Hispanic whites. In fact, the data suggest the possibility that the pro-

portion that is undiagnosed in these groups has decreased over the last decade. Possible explanations for such a decrease are lacking. Decreases over the past several decades in the proportion of diabetes that is undiagnosed have occurred only among the most obese (19).

We found a higher prevalence of both diagnosed and undiagnosed diabetes in men than in women among non-Hispanic whites, but a similar prevalence by sex among non-Hispanic blacks and Mexican Americans. Whether this difference by race/ethnicity is a function of higher prevalences of overweight and obesity among non-Hispanic black and Mexican-

American women (18) may warrant further research.

Interestingly, the prevalence of IFG in non-Hispanic blacks was substantially lower than that in non-Hispanic whites and Mexican Americans, despite the prevalence of diagnosed diabetes in non-Hispanic blacks being twice as high as that in non-Hispanic whites and similar to that in Mexican Americans. This finding also merits further research.

Lifestyle modification such as weight management and increased physical activity reduces the risk of diabetes among persons with IGT (20). However, there are no signs that obesity is abating (18), and features of insulin resistance are evident in adolescents with IFG (21). The prevalence of diagnosed diabetes has increased significantly over the last decade. Although the prevalences of undiagnosed diabetes and IFG have remained relatively stable, the current prevalences of total diabetes and IFG are excessive relative to national health objectives (22), particularly in minority groups.

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