Full Accounting of Diabetes and Pre-Diabetes in the U.S. Population in 1988–1994 and 2005–2006

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OBJECTIVE — We examined the prevalences of diagnosed diabetes, and undiagnosed diabetes and pre-diabetes using fasting and 2-h oral glucose tolerance test values, in the U.S. during 2005–2006. We then compared the prevalences of these conditions with those in 1988–1994.

RESEARCH DESIGN AND METHODS — In 2005–2006, the National Health and Nutrition Examination Survey included a probability sample of 7,267 people aged ≥12 years. Participants were classified according to glycemic status by interview for diagnosed diabetes and by fasting and 2-h glucose levels measured in subsamples.

RESULTS — In 2005–2006, the crude prevalence of total diabetes in people aged ≥20 years was 12.9%, of which ~40% was undiagnosed. In people aged ≥20 years, the crude prevalence of impaired fasting glucose was 25.7% and of impaired glucose tolerance was 13.8%, with almost 30% having both. Over 40% of individuals had diabetes or pre-diabetes. Almost one-third of the elderly had diabetes, and three-quarters had diabetes or pre-diabetes. Compared with non-Hispanic whites, age- and sex-standardized prevalence of diabetes was approximately twice as high in non-Hispanic blacks (P < 0.0001) and Mexican Americans (P = 0.0001), whereas undiagnosed diabetes was not higher. Crude prevalence of diabetes in people aged ≥20 years rose from 5.1% in 1988–1994 to 7.7% in 2005–2006 (P = 0.0001); this was significant after accounting for differences in age and sex, particularly in non-Hispanic blacks. Prevalences of undiagnosed diabetes and pre-diabetes were generally stable, although the proportion of total diabetes that was undiagnosed decreased in Mexican Americans.

CONCLUSIONS — Over 40% of people aged ≥20 years have hyperglycemic conditions, and prevalence is higher in minorities. Diagnosed diabetes has increased over time, but other conditions have been relatively stable.

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Prevalence of diabetes and pre-diabetes

RESEARCH DESIGN AND METHODS — NHANES 2005–2006 was conducted by the National Center for Health Statistics (11). NHANES is designed to be representative of the U.S. civilian noninstitutionalized population using a complex, multistage probability sample. Participants are interviewed in their homes and subsequently receive a physical and laboratory examination in a mobile examination center. Among eligible subjects in 2005–2006, 77.7% were interviewed and 74.9% were examined (11).

In 2005–2006, 7,267 individuals aged ≥12 years completed the household interview (online appendix Figure A1 [available at http://dx.doi.org/10.2337/dc08-1296]). Questions covered demographic characteristics and medical conditions. Individuals were asked whether, other than during pregnancy for women, a doctor or health care professional had ever told them that they have diabetes. There were 516 individuals aged ≥12 years classified as having diagnosed diabetes.

Households were randomized to either a morning or afternoon/evening examination session. There were 3,107 individuals aged ≥12 years without diagnosed diabetes examined during a morning session, and plasma glucose values were obtained from 2,662 (86%) of them after they fasted for 8 to <24 h. This group is subsequently referred to as the FPG subsample. Pregnant women (n = 162) were included, none of whom had undiagnosed diabetes based on FPG.

Individuals assigned to the morning examination underwent an OGTT (11). A 75-g glucose-equivalent oral glucose challenge (Trutol) was given, and a blood sample was drawn 2 h (±15 min) later. Exclusion criteria included use of insulin or oral medications for diabetes, known pregnancy, hemophilia, chemotherapy, refusal of phlebotomy, and inability to drink all of the Trutol. The 2-h glucose value was obtained for 2,290 (86%) of those in the FPG sample. This group is subsequently referred to as the OGTT subsample.

Procedures for blood collection and processing are described elsewhere (11). Plasma glucose was measured at a central laboratory using a hexokinase enzymatic method (11), with a coefficient of variation of 1.3–2.2% (11). A1C was measured by a high-performance liquid chromatographic assay (11). Because there were changes to the equipment and laboratory that measured glucose and A1C since the earlier NHANES surveys, conversion factors were applied to values from 2005–2006 to make them comparable with values from NHANES III (1988–1994) (11).

Standard diagnostic criteria were used to classify people without diagnosed diabetes as to whether they had undiagnosed diabetes (FPG ≥7.0 mmol/l and/or 2-h glucose ≥11.1 mmol/l) or pre-diabetes (IFG [FPG 5.6 to <7.0 mmol/l] and/or IGT [2-h glucose 7.8 to <11.1 mmol/l]) (12).

Estimates from NHANES 2005–2006 are compared with those from NHANES 1988–1994. NHANES 1988–1994 used similar interview questions on previous diagnosis of diabetes (13,14). Collection methods for blood specimens were the same across the surveys (13). In 1988–1994, the OGTT was only performed in individuals aged 40–74 years.

For NHANES 2005–2006, individuals with diagnosed diabetes from the interviewed sample were combined with individuals without diagnosed diabetes from the FPG subsample for estimates involving FPG, or the OGTT subsample for estimates involving 2-h glucose (online appendix Figure A1). Appropriate sampling weights were used so that the sum of the sample weights from the two groups (interview and FPG or OGTT subsample) added to the total U.S. population. For NHANES 1988–1994, prevalences of normal glucose and undiagnosed diabetes (based on FPG or 2-h glucose), IFG, and IGT in the subsamples of people without diagnosed diabetes were each adjusted for the prevalence of diagnosed diabetes from the interviewed sample so that the sum of all diagnostic categories added to the total U.S. population (15). This difference in approach for NHANES 1988–1994 was required because sampling weights provided for the FPG and OGTT subsamples for that survey did not account for some individuals having invalid or unknown fasting times or unknown plasma glucose values.

We standardized estimates to the U.S. 2000 Census population by age and sex using the direct method with age categories of 12–19, 20–39, 40–59, and ≥60 years for estimates in people aged ≥12 and ≥20 years and age categories of 40–59 and 60–74 years for estimates in those aged 40–74 years. The ratio of undiagnosed to total diabetes was also standardized to the total U.S. 2000 Census population. SUDAAN (16) was used to calculate SEs in NHANES 2005–2006 based on the Taylor series linearization method (17). For NHANES 1988–1994, variance estimates were based on Fay’s modified balanced repeated replication (18), reflecting the method used to combine the interviewed and FPG/OGTT subsamples.

For NHANES 2005–2006, we used one-sample Student’s t tests for testing whether differences between subgroups in proportions were significantly different from zero. Two-sample Student’s t tests were used to test differences in proportions between the two surveys. A P value ≤0.05 was considered statistically significant. The degrees of freedom used reflect the complex sample design.

RESULTS

Prevalences in 2005–2006

Diagnosed diabetes. The crude prevalence of diagnosed diabetes in individuals aged ≥20 years was 7.7% (Table 1). Prevalence increased with age and peaked at age 60–74 years (crude 17.6%), falling slightly in older ages. Crude and standardized prevalences were similar in men and women. Crude prevalence was significantly higher in non-Hispanic blacks (12.8%) than in non-Hispanic whites (6.6%; P < 0.0001) and Mexican Americans (8.4%; P = 0.008); standardized prevalences were significantly higher in non-Hispanic blacks (P < 0.0001) and Mexican Americans (P = 0.0001) than in non-Hispanic whites.

Undiagnosed diabetes (FPG). The crude prevalence of undiagnosed diabetes based on FPG was 2.5% among individuals aged ≥20 years (Table 1). Prevalence was much higher in those aged ≥60 years than in people of younger ages. The higher prevalences of undiagnosed diabetes in men than in women were not significantly different (crude P = 0.12; standardized P = 0.08). There were no statistically significant differences between race/ethnic groups.

Undiagnosed diabetes (2-h OGTT glucose). The crude prevalence of undiagnosed diabetes based on 2-h glucose was 4.9% among people aged ≥20 years, approximately twofold higher than prevalences of undiagnosed diabetes based on FPG (Table 1). Similar to the case of undiagnosed diabetes based on FPG, prevalence based on 2-h glucose was much higher in those aged ≥60 years than in those of younger ages. No differences in prevalence were found by sex. Standardized prevalence of undiagnosed diabetes...
|                        | Diagnosed diabetes | Undiagnosed diabetes | Total diabetes (diagnosed and undiagnosed by FPG or OGTT) | Proportion of total diabetes that is undiagnosed§ |
|------------------------|--------------------|-----------------------|----------------------------------------------------------|--------------------------------------------------|
|                        | n                  | n                     | n                                | n                                                                 |
| Crude prevalence       |                    |                       |                                  |                                                                   |
| Combined age-groups     |                    |                       |                                  |                                                                   |
| ≥12                    | 3,178              | 3,178                 | 2,806                           | 2,806                                                             | 2,806 |
|                        | 6.7 (5.8–7.7)      | 2.1 (1.1–3.2)         | 4.2 (3.0–5.5)                   | 4.4 (3.1–5.7)                                                     | 11.1 (9.3–13.0) |
|                        | 7.7 (6.7–8.8)      | 2.5 (1.2–3.7)         | 4.9 (3.4–6.4)                   | 5.1 (3.6–6.6)                                                     | 12.9 (10.8–14.9) |
|                        | 17.0 (14.9–19.0)   | 6.6 (2.7–10.5)        | 14.3 (9.6–19.0)                 | 14.6 (10.0–19.2)                                                 | 31.6 (25.7–37.6) |
| Age-specific groups     |                    |                       |                                  |                                                                   |
| 12–19                  | 0.2 (0.0–0.5)¶     | 0.1 (0.0–0.1)¶       | 0.0                             | 0.1 (0.0–0.2)¶                                                   | 0.3 (0.0–0.6)¶ |
|                        | 2.1 (1.5–2.8)      | 0.8 (0.2–1.3)         | 0.9 (0.4–1.4)                   | 1.0 (0.4–1.6)                                                    | 3.1 (2.4–3.9)  |
|                        | 7.9 (6.3–9.5)      | 1.9 (0.4–3.4)         | 4.2 (1.8–6.5)                   | 4.5 (2.1–6.9)                                                    | 12.4 (9.0–15.8) |
|                        | 17.6 (14.9–20.3)   | 6.7 (2.1–11.4)        | 12.4 (6.7–18.2)                 | 12.8 (7.1–18.4)                                                 | 30.0 (23.0–37.0) |
| ≥75                    | 14.9 (11.1–18.8)   | 5.4 (1.1–9.8)         | 13.4 (9.3–17.5)                 | 13.4 (9.3–17.5)                                                 | 29.1 (24.8–33.3) |
| Sex by age (years)     |                    |                       |                                  |                                                                   |
| Men                    |                    |                       |                                  |                                                                   |
| ≥12                    | 6.2 (4.9–7.5)      | 2.9 (1.1–4.6)         | 4.2 (2.3–6.0)                   | 4.5 (2.6–6.4)                                                    | 10.7 (8.1–13.2) |
|                        | 7.2 (5.7–8.7)      | 3.3 (1.3–5.3)         | 4.9 (2.8–7.0)                   | 5.2 (3.0–7.4)                                                    | 12.4 (9.6–15.2) |
| Women                  |                    |                       |                                  |                                                                   |
| ≥12                    | 7.2 (5.7–8.7)      | 1.5 (0.5–2.4)         | 4.3 (2.9–5.7)                   | 4.4 (2.8–5.9)                                                    | 11.6 (9.1–14.1) |
|                        | 8.3 (6.5–10.0)     | 1.7 (0.6–2.8)         | 4.9 (3.3–6.5)                   | 5.0 (3.3–6.8)                                                    | 13.3 (10.5–16.1) |
| Race/ethnicity by age  |                    |                       |                                  |                                                                   |
| Non-Hispanic white     |                    |                       |                                  |                                                                   |
| ≥12                    | 5.8 (4.6–7.1)      | 2.3 (0.8–3.7)         | 4.8 (3.0–6.6)                   | 4.9 (3.0–6.8)                                                    | 10.7 (8.2–13.3) |
|                        | 6.6 (5.3–7.9)      | 2.6 (0.9–4.2)         | 5.5 (3.4–7.5)                   | 5.6 (3.5–7.7)                                                    | 12.2 (9.4–15.0) |
| Non-Hispanic black     |                    |                       |                                  |                                                                   |
| ≥12                    | 10.6 (8.9–12.4)    | 2.6 (1.3–3.8)         | 2.9 (1.9–3.9)                   | 3.4 (1.5–5.3)                                                    | 14.1 (11.5–16.6) |
|                        | 12.8 (10.6–15.1)   | 3.1 (1.7–4.5)         | 3.5 (2.4–4.6)                   | 4.1 (2.0–6.2)                                                    | 17.0 (14.4–19.7) |
| Mexican American       |                    |                       |                                  |                                                                   |
| ≥12                    | 6.9 (5.1–8.8)      | 2.9 (1.1–4.8)         | 4.6 (1.8–7.5)                   | 5.3 (2.4–8.1)                                                    | 12.2 (8.0–16.4) |
|                        | 8.4 (6.3–10.6)     | 3.5 (1.1–5.8)         | 5.7 (2.2–9.2)                   | 6.3 (2.7–9.9)                                                    | 14.7 (9.5–20.0) |
| Standardized* prevalence Combined age-groups (years) |                    |                       |                                  |                                                                   |
| ≥12                    | 6.6 (5.8–7.3)      | 2.1 (1.2–3.0)         | 4.1 (3.0–5.3)                   | 4.3 (3.2–5.4)                                                    | 10.9 (9.5–12.3) |
|                        | 7.6 (6.7–8.5)      | 2.4 (1.4–3.5)         | 4.8 (3.5–6.1)                   | 5.0 (3.7–6.3)                                                    | 12.6 (10.9–14.3) |
|                        | 16.9 (14.8–19.0)   | 6.6 (2.7–10.5)        | 14.1 (9.5–18.7)                 | 14.4 (9.9–18.9)                                                 | 31.4 (25.3–37.4) |
| Age-specific groups (years) |                    |                       |                                  |                                                                   |
| 12–19                  | 0.2 (0.0–0.5)¶     | 0.1 (0.0–0.1)¶       | 0.0                             | 0.1 (0.0–0.2)¶                                                   | 0.3 (0.0–0.6)¶ |
| 20–39                  | 2.1 (1.5–2.8)      | 0.7 (0.2–1.3)         | 0.9 (0.4–1.4)                   | 1.0 (0.4–1.5)                                                    | 3.1 (2.4–3.8)  |
| 40–59                  | 7.9 (6.3–9.5)      | 1.9 (0.4–3.4)         | 4.2 (1.8–6.5)                   | 4.5 (2.1–6.9)                                                    | 12.4 (9.0–15.8) |
| 60–74                  | 17.5 (14.8–20.3)   | 6.8 (2.0–11.5)        | 12.4 (6.6–18.3)                 | 12.8 (7.1–18.5)                                                 | 29.9 (22.9–37.0) |
| ≥75                    | 14.8 (11.1–18.5)   | 5.7 (1.4–10.0)        | 13.2 (9.3–17.2)                 | 13.2 (9.3–17.2)                                                 | 28.8 (24.6–32.9) |
| Sex by age (years)     |                    |                       |                                  |                                                                   |
| Men                    |                    |                       |                                  |                                                                   |
| ≥12                    | 6.3 (4.9–7.6)      | 2.9 (1.3–4.6)         | 4.3 (2.6–6.0)                   | 4.6 (2.9–6.3)                                                    | 10.9 (8.8–13.0) |
|                        | 7.3 (5.8–8.8)      | 3.4 (1.5–5.3)         | 5.0 (3.0–6.9)                   | 5.3 (3.3–7.3)                                                    | 12.6 (10.1–15.0) |
Prevalence of diabetes and pre-diabetes

Table 1—Continued

| Race/ethnicity by age (years) | Total diabetes | Pre-diabetes | Total pre-diabetes | Proportion of total diabetes that is undiagnosed $^*$ |
|------------------------------|----------------|--------------|-------------------|--------------------------------------------------|
|                              | Diagnosed diabetes | Undiagnosed diabetes | (diagnosed and undiagnosed by FPG or OGTT) | |
|                              | FPG† | OGTT‡ | Total (FPG or OGTT) | |
| Women                        |      |      |                      |                                               |
| $\geq 12$                    | 6.8  (5.5–8.1) | 1.4 (0.5–2.3) | 3.9 (2.7–5.2) | 4.0 (2.7–5.4) | 10.8 (8.9–12.8) | # |
| $\geq 20$                    | 7.9  (6.4–9.3) | 1.6 (0.5–2.6) | 4.6 (3.1–6.0) | 4.7 (3.1–6.3) | 12.5 (10.3–14.8) | ** |
| Mexican American             |      |      |                      |                                               |
| $\geq 12$                    | 10.9 (8.7–13.1) | 3.2 (1.7–4.7) | 6.0 (4.0–8.0) | 6.5 (4.7–8.4) | 17.4 (13.9–21.0) | # |
| $\geq 20$                    | 12.6 (10.0–15.2) | 3.7 (1.9–5.5) | 7.0 (4.7–9.3) | 7.5 (5.2–9.8) | 20.1 (15.9–24.2) | ** |

Race/ethnicity by age

Data are % (95% CI). Diagnosed diabetes determined by self-report on interview. Values by age alone and by sex include those of race/ethnic groups not listed separately. *Estimates for the total population aged $\geq 12$ and $\geq 20$ years and for race/ethnic groups were age and sex standardized, estimates for age-specific groups including those aged $\geq 65$ years were sex standardized, and estimates for sex groups were age standardized (all using the 2000 U.S. Census population). †FPG $\leq 7.0$ mmol/l. ‡2-h plasma glucose $\leq 11.1$ mmol/l. §Estimates in this section have a denominator of total diabetes, whereas all other estimates have a denominator of the total population. Relative SE $>30\%$: the confidence interval is wide, relative to the size of the estimate. #Rounded to zero as method of calculating confidence intervals led to lower bounds that were slightly below zero. **There was no undiagnosed diabetes in women aged 20–39 years; therefore, the standardized estimate and associated confidence interval are unreliable.

Based on 2-h glucose was significantly higher in Mexican Americans compared with non-Hispanic blacks (7.0 vs. 4.1%; $P = 0.04$) but not compared with non-Hispanic whites (7.0 vs. 4.9%; $P = 0.14$). The combined crude prevalence of undiagnosed diabetes based on FPG or 2-h glucose was 5.1% in people aged $\geq 20$ years (Table 1). Prevalence was much higher in people aged $\geq 60$ years than in those of younger ages. Prevalence did not differ significantly by sex or race/ethnicity, even in Mexican Americans compared with non-Hispanic whites and non-Hispanic blacks (standardized, both $P = 0.07$).

Total diabetes. The combined crude prevalence of diabetes, based on diagnosed and undiagnosed diabetes detected by FPG or 2-h glucose, was 12.9% in people aged $\geq 20$ years (Table 1). Total prevalence of diabetes increased steadily with age and peaked at about 30% in all age groups $\geq 60$ years. Total diabetes prevalence was virtually the same in men and women. Compared with non-Hispanic whites aged $\geq 20$ years, total diabetes prevalence was about 70% higher in non-Hispanic blacks ($P < 0.0001$) and 80% higher in Mexican Americans ($P = 0.0008$) after accounting for differences in age and sex distributions. The proportion of total diabetes that was undiagnosed was almost 40% in those aged $\geq 20$ years and increased moderately with age (Table 1). The proportion of total diabetes that was undiagnosed was similar in men and women aged $\geq 20$ years. A significantly higher proportion was undiagnosed in non-Hispanic whites aged $\geq 20$ years (crude 46.0%) and Mexican Americans (crude 43.0%) than in non-Hispanic blacks (24.2%; both $P = 0.02$); racial differences were not explained by different age and sex distributions, as shown in the standardized ratios. IFG. In individuals aged $\geq 20$ years, 25.7% had IFG (Table 2). IFG increased with age, doubling between ages 20–39 and 40–59 years, and then remained constant at $\geq 60$ years. IFG prevalence was significantly higher in men (crude 32.1%) than in women (crude 19.8%; both crude and standardized $P < 0.0001$). No statistically significant differences in prevalence were observed by race/ethnicity. IGT. IGT was found in 13.8% of those aged $\geq 20$ years, about half the prevalence of IFG (Table 2). Prevalence steadily increased with age, peaking at 35.1% in those aged $\geq 75$ years. Prevalences did not differ significantly by sex or race/ethnicity.

Total pre-diabetes. The crude prevalence of either IFG or IGT was 29.5% among people aged $\geq 20$ years (Table 2). Prevalence increased with age, peaking at age $\geq 75$ years (crude 46.7%). Prevalence was much higher in men than in women (aged $\geq 20$ years crude 36 vs. 23.4% and standardized 35.7 vs. 22.8%; both $P = 0.0002$). The somewhat higher prevalence in Mexican Americans than in non-Hispanic whites or non-Hispanic blacks was not significantly different.

Total diabetes (diagnosed and undiagnosed) and pre-diabetes (IFG and IGT). The total combined crude prevalence of diabetes and pre-diabetes was 42.3% in people aged $\geq 20$ years (Table 2 and online appendix Figures A2 and A3). Prevalence rose steadily with age, with crude prevalence reaching 75.7% in people aged $\geq 75$ years. Prevalence of any hyperglycemic condition was much higher in men than in women (aged $\geq 20$ years crude 48.4 vs. 36.7%; $P = 0.0002$; standardized 48.3 vs. 35.4%; $P = 0.0001$), explained largely by the higher preva-
Table 2—Crude and standardized* prevalence of IFG, IGT, total pre-diabetes, and total diabetes and pre-diabetes, NHANES 2005–2006

|                      | IFG          | IGT          | Total pre-diabetes (IFG or IGT) | Total diabetes and pre-diabetes |
|----------------------|--------------|--------------|---------------------------------|---------------------------------|
| **n**                | 3,178        | 2,806        | 2,806                           | 2,806                           |

**Crude prevalence**

|                    | Combined age-groups (years) | Age-specific groups (years) | Sex by age (years) | Race/ethnicity by age (years) | Standardized* prevalence |
|--------------------|-----------------------------|----------------------------|--------------------|-------------------------------|--------------------------|
| **n**              | 3,178                       | 2,806                      | 2,806              | 2,806                         |                          |
|                    | 12                          | 20                         | 65                 | 12–19                         |                          |
|                    | ≥12                         | ≥20                        | ≥65                | ≥12                           |                          |
|                    | 12.7 (8.9–16.6)             | 12.1 (10.3–15.9)           | 31.3 (24.3–38.3)   | 17.9 (15.6–20.3)              |                          |
|                    | 23.7 (20.7–27.2)            | 13.8 (11.2–16.5)           | 26.9 (21.0–32.7)   | 12.0 (9.2–14.7)               |                          |
|                    | 124.0 (22.0–27.2)           | 13.8 (11.2–16.5)           | 26.9 (21.0–32.7)   | 12.0 (9.2–14.7)               |                          |
|                    | (10.0–14.8)                 | (11.2–16.5)                | (21.0–32.7)        | (9.2–14.7)                    |                          |
| **Total pre-diabetes** | 27.6 (24.9–30.7)               | 29.5 (26.2–32.7)           | 40.4 (34.4–46.3)    | 21.6 (18.8–24.4)              |                          |
| **Total diabetes and pre-diabetes** | 38.7 (34.5–43.0)               | 42.3 (37.9–46.7)           | 72.0 (66.7–77.3)     | 44.7 (38.9–50.4)              |                          |

Data are % (95% CI). Values by age alone and by sex in people aged ≥12 and ≥20 years include those of race/ethnic groups not listed separately. *Estimates for the total population aged ≥12 and ≥20 years and for race/ethnic groups were age and sex standardized, estimates for age-specific groups including those aged ≥65 years were sex standardized, and estimates for sex groups were age standardized (all using the 2000 U.S. Census population). IFG, FPG 5.6–7.0 mmol/l; IGT, 2-h plasma glucose 7.8–11.1 mmol/l.

Total diabetes includes diagnosed diabetes (determined by self-report on interview) and undiagnosed diabetes (FPG ≥7.0 mmol/l or 2-h plasma glucose ≥11.1 mmol/l).
Prevalence of diabetes and pre-diabetes

Table 3—Distribution of FPG and 2-h (OGTT) plasma glucose diagnostic categories, and mean A1C, in U.S. adults aged ≥20 years, NHANES 2005–2006

| Diagnostic category based on FPG | Diagnostic category based on 2-h glucose | Distribution across 2-h glucose categories by FPG diagnostic category | Distribution across FPG and 2-h glucose diagnostic categories | A1C (%) |
|--------------------------------|----------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------|
| Undiagnosed diabetes          | Undiagnosed diabetes                   | 91.0 (74.0–97.3)                                              | 2.3 (1.3–4.0)                                                | 7.04 (6.37–7.70) |
|                               | IGT                                    | 1.4* (0.1–12.7)                                               | 0.0*†                                                        | †       |
|                               | Normal                                 | 7.6* (2.3–22.2)                                               | 0.2* (0.1–0.7)                                               | ‡       |
| IFG                           | Undiagnosed diabetes                   | 8.5 (5.9–12.2)                                                | 2.2 (1.5–3.3)                                                | 5.80 (5.71–5.88) |
|                               | IGT                                    | 31.3 (24.3–39.2)                                              | 8.1 (5.9–11.0)                                               | 5.66 (5.60–5.73) |
|                               | Normal                                 | 60.2 (52.6–67.3)                                              | 15.7 (13.7–17.9)                                             | 5.50 (5.46–5.55) |
| Normal                        | Undiagnosed diabetes                   | 0.6* (0.3–1.5)                                                | 0.4* (0.2–0.9)                                              | ‡       |
|                               | IGT                                    | 8.9 (6.4–12.2)                                                | 5.7 (4.1–7.8)                                                | 5.44 (5.39–5.50) |
|                               | Normal                                 | 90.5 (87.2–93.0)                                              | 57.7 (53.2–62.0)                                             | 5.28 (5.25–5.30) |
| Diagnosed diabetes            |                                        | 100.0                                                        |                                                               |         |

Data are % (95% CI) except for A1C values, which are means (95% CI). *Relative standard error >30%: the confidence interval is wide, relative to the size of the estimate. †Rounds to zero. ‡ In < 30. Undiagnosed diabetes determined by either FPG ≥7.0 mmol/l or 2-h plasma glucose ≥11.1 mmol/l. IFG, FPG 5.6–7.0 mmol/l; IGT, 2-h plasma glucose 7.8–11.1 mmol/l; diagnosed diabetes determined by self-report on interview.

Prevalence of diabetes in men. Whereas crude prevalence of any hyperglycemic condition was not significantly different by race/ethnicity, standardized prevalence was significantly higher in non-Hispanic blacks (aged ≥20 years 44.9% vs. whites [38.7%]; P = 0.01) and significantly higher in Mexican Americans (52.0%) compared with non-Hispanic whites (P = 0.004) but not compared with non-Hispanic blacks (P = 0.06).

Comparison of FPG and 2-h glucose values

Among those classified as diabetic or normal by FPG, >90% were classified likewise by 2-h glucose (Table 3). However, whereas the prevalence of undiagnosed diabetes by FPG was 2.5%, the prevalence by either definition was 5.1%; when combined with diagnosed diabetes, total diabetes was 10.2 and 12.9%, respectively. For people with IFG, there was much less agreement between the classifications. Only 31.3% of those with IFG also had IGT, comprising 8.1% of the population. Among those defined as having IFG, 8.5% were classified as having diabetes based on 2-h glucose. This largely explains the doubling of the prevalence of undiagnosed diabetes based on 2-h glucose compared with undiagnosed diabetes based on FPG, as described earlier; 2.2% of the population comprised this category. In contrast, 60% of those with IFG were classified by 2-h glucose as having normal glucose tolerance. This explains the approximate halving of prevalence of pre-diabetes based on the 2-h glucose, compared with the prevalence of IFG, as described earlier. Although 8.5% of those with IFG were classified by 2-h glucose as having diabetes, the mean A1C of this group (5.80%) was within the normal range.

Trends in prevalences from 1988–1994 to 2005–2006

The crude prevalence of diagnosed diabetes in individuals aged ≥20 years rose significantly from 5.1% in 1988–1994 to 7.7% in 2005–2006 (P = 0.0001) (online appendix Tables A1 and A2); this was significant after accounting for differences in age/sex distributions between the two surveys (P = 0.0002). The rise in prevalence occurred for all groups but was particularly dramatic for non-Hispanic blacks (crude 6.9 to 12.8%, P < 0.0001; standardized 8.4 to 13.9%, P < 0.0001). There were no significant changes between the surveys in prevalence of undiagnosed diabetes (FPG, 2-h glucose, or total undiagnosed); however, the small sample sizes in 2005–2006 may limit the ability to detect changes for subgroups. Total diabetes (diagnosed and undiagnosed) prevalence changed significantly only for non-Hispanic blacks (aged 40–74 years crude 20.3 to 26.1%, P = 0.007; standardized 20.2 to 27.1%, P = 0.001). Whereas the proportion of total diabetes that was undiagnosed appeared to decrease between the surveys for all groups, changes were only significant in Mexican Americans (aged 40–74 years crude 44.9 to 30.0%; P = 0.02).

There was no substantial change in prevalence of IFG or IGT between 1988–1994 and 2005–2006. Likewise, total pre-diabetes (IFG or IGT) did not change significantly except in Mexican Americans (aged 40–74 years standardized 53.3 to 61.4%; P = 0.01). The decrease in prevalence in Mexican Americans was not significant (aged 40–74 years standardized 67.1 to 59.8%; P = 0.06).

CONCLUSIONS—These recent data indicate that 12.9% of the adult U.S. population aged ≥20 years have diabetes (7.7% previously diagnosed and 5.1% undiagnosed), of which 39.8% is undiagnosed. Another 29.5% of the population is at risk of diabetes based on having pre-diabetes (IFG or IGT). Overall, approximately 40% of the U.S. population has some hyperglycemic condition. The el-
OLDER POPULATION IS PARTICULARLY SUSCEPTIBLE, WITH ABOUT ONE-THIRD HAVING DIAGNOSED OR UNDIAGNOSED DIABETES AND THREE-QUARTERS HAVING DIABETES OR PRE-DIABETES. MINORITY GROUPS CONTINUE TO SUFFER PROPORTIONALLY, AS PREVALENCE OF DIAGNOSED AND UNDIAGNOSED DIABETES COMBINED IS 70–80% HIGHER IN NON-HISPANIC BLACKS AND MEXICAN AMERICANS THAN IN NON-HISPANIC WHITE SUBJECTS. BUT WHEREAS DIAGNOSED DIABETES HAS RISEN SIGNIFICANTLY OVER THE LAST 10–15 YEARS, PARTICULARLY IN NON-HISPANIC BLACKS, UNDIAGNOSED DIABETES AS A PROPORTION OF TOTAL DIABETES HAS REMAINED RELATIVELY STABLE AND MAY BE DECREASING, PARTICULARLY IN MEXICAN AMERICANS.

NHANES IS UNIQUE BECAUSE ITS RESULTS REPRESENT PEOPLE IN THE U.S. NONINSTITUTIONALIZED POPULATION, AND THE SURVEY, IN CONTRAST WITH OTHER NATIONAL SURVEYS, INCLUDES A LABORATORY COMPONENT THAT MEASURES FPG. NHANES WAS PARTICULARLY UNIQUE IN 2005–2006 BECAUSE OF INCLUSION OF AN OGTT NOT PREVIOUSLY PERFORMED SINCE 1988–1994. THE FPG IS RECOMMENDED FOR SCREENING FOR DIABETES AND IFG BECAUSE IT IS MORE REPRODUCIBLE AND CONVENIENT AND LESS COSTLY. FPG AND 2-H OGTT GLUCOSE, HOWEVER, MEASURE DIFFERENT PHYSIOLOGICAL PHENOMENA (4).

TWO-HOUR GLUCOSE IS MORE SENSITIVE THAN FPG TO DETECTING GLUCOSE DEFECTS IN THE ELDERLY (7). WHEREAS 91% OF PEOPLE HAVING DIABETES BY FPG WERE LIKELY CLASSIFIED BY 2-H GLUCOSE, THE 2-H GLUCOSE ADDED ANOTHER 2.6% OF DIABETES PREVALENCE. THE CORRESPONDING FIGURE AMONG PEOPLE AGED 40–74 YEARS IN NHANES 1988–1994 WAS 2.0%, WHICH IS NOT SIGNIFICANTLY DIFFERENT (9). THERE WAS SUBSTANTIAL DISAGREEMENT AMONG THOSE HAVING IFG, IN WHOM 8.5% WERE DIABETIC AND 60.2% NORMOGLYCEMIC BASED ON 2-H GLUCOSE. THIS EXPLAINS THE DOUBLING OF THE PREVALENCE OF UNDIAGNOSED DIABETES BASED ON 2-H GLUCOSE (AGED ≥20 YEARS CRUDE 2.5% BY FPG, 4.9% BY 2-H GLUCOSE, AND 5.1% HAVING EITHER) AND HALVING OF PRE-DIABETES (AGED ≥20 YEARS CRUDE 25.7% BY FPG, 13.8% BY 2-H GLUCOSE, AND 29.5% HAVING EITHER).

WE NOTE THAT DETECTION OF UNDIAGNOSED DIABETES AND PRE-DIABETES BY EITHER FPG OR 2-H GLUCOSE WAS BASED ON A SINGLE PLASMA GLUCOSE READING FROM SUBJECTS WHO SELF-REPORTED THAT THEY FASTED APPROPRIATELY, WHEREAS RETESTING IS SUGGESTED FOR DIAGNOSIS IN A CLINICAL SETTING. CONSEQUENTLY, SOME OF THE PREVALENCE ESTIMATES MAY BE OVERSTATED. IN ADDITION, THE AVAILABLE SAMPLE SIZE IN 2005–2006 LIMITED THE ABILITY TO DETECT DIFFERENCES. Nevertheless, some important differences were detected between groups and over time.

As shown in previous reports (3), diagnosed diabetes remains more than twice as high in non-Hispanic blacks and Mexican Americans than in non-Hispanic whites, after accounting for differences in age and sex distributions. The racial/ethnic disparity is reflected in prevalence of total diabetes (diagnosed and undiagnosed) and total hyperglycemic conditions. Undiagnosed diabetes was not greater in these groups.

Diagnosed diabetes increased significantly between 1988–1994 and 2005–2006 in all age groups and in both men and women. The rise in prevalence of diagnosed diabetes was particularly prominent in non-Hispanic blacks and was reflected in a rise in total diabetes and total hyperglycemic conditions over time (most prominently in non-Hispanic blacks).

Based on both FPG and 2-h glucomes, almost 40% of total diabetes was undiagnosed. The proportion that was undiagnosed was significantly higher in non-Hispanic whites than in Mexican Americans. The proportion of total diabetes that was undiagnosed tended to decrease between the surveys, but this was statistically significant only among Mexican Americans.

Thus, whereas diagnosed and total diabetes and total hyperglycemic conditions remain disproportionately high in minority groups, it may be that diabetes is being diagnosed more frequently in these groups, both over time and relative to non-Hispanic whites. This was also found when comparing data from 1999–2002 with those from 1988–1994 (3). More focused screening may be occurring in these groups (19). Decreases over the past several decades in the proportion of diabetes that is undiagnosed have occurred only among the most obese (20). We also found that pre-diabetes decreased significantly over time in Mexican Americans.

Overall, almost 30% of the population had pre-diabetes (IFG or IGT), a condition that increases the risk for diabetes and is associated with other cardiovascular risk factors (4,8). In 2005–2006, IFG was 70% higher in men than in women, consistent with findings in 1999–2002 (3). This was reflected in their higher prevalences of total pre-diabetes and total hyperglycemic conditions. No differences by sex, however, were found in the prevalence of diagnosed or undiagnosed diabetes. These observations currently lack explanation. It is encouraging that prevalence of pre-diabetes did not appear to increase between the surveys; this is surprising given the increase in diagnosed diabetes and obesity (10) over time.

The sheer magnitude of prevalence of hyperglycemic conditions found in 2005–2006 portends all the consequences of diabetes including its myriad of complications and costs both to individuals and to society. The prevalence of diabetes continues to increase over time but appears to be recognized more commonly. Despite some evidence that overweight and obesity may be plateauing in adults (21) and adolescents (22), their prevalences remain high; and, even in adolescents, features of insulin resistance are found in the presence of IFG (23). Lifestyle modification including weight management and increased physical activity should be prescribed and practiced in those with diabetes (24) and pre-diabetes (25), particularly in minority groups.

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