Trends in Hospitalizations for Diabetes Among Children and Young Adults

United States, 1993–2004

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OBJECTIVE — The purpose of this study was to examine national trends in hospitalizations associated with diabetes for U.S. children and young adults.

RESEARCH DESIGN AND METHODS — The study included hospital discharges for individuals aged 0–29 years with a diagnosis of diabetes (250.xx) in the Nationwide Inpatient Sample (1993–2004). Outcomes were weighted, nationally representative estimates of the frequency of population-adjusted hospital discharges and hospital charges (2004 $U.S.).

RESULTS — Among individuals aged 0–29 years, population-adjusted rates of hospitalizations associated with diabetes over the 12-year period increased by 38% (99.1 of 100,000 in 1993 and 136.4 of 100,000 in 2004; $P < 0.001$ for curvilinear trend). Age-specific increases in annual hospitalizations for diabetes occurred primarily among individuals aged 20–24 years (152.6 of 100,000 in 1993 and 222.2 of 100,000 in 2004) and 25–29 years (224.9 of 100,000 in 1993 and 331.2 of 100,000 in 2004). Trends in hospitalizations among younger individuals showed no significant patterns. Hospitalization rates were consistently higher for females than for males, with a greater rate of increase for females (42%) than for males (29%) ($P < 0.001$). Inflation-adjusted total charges for diabetes hospitalizations increased 130%, from $1.05 billion in 1993 to $2.42 billion in 2004.

CONCLUSIONS — The number of young adults hospitalized with diabetes in the U.S. has increased significantly over the last decade. Sex-specific differences in hospitalization rates and trends in obesity among U.S. children may amplify future trends in diabetes hospitalizations and corresponding rapid growth in associated health care expenditures.

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Studies indicate that the burden of diabetes, type 1 and type 2, is substantial (1) and rising among U.S. children (2–4). Diabetes registries in Philadelphia (5), Pittsburgh (6), and Chicago (3) have reported increasing rates of type 1 diabetes throughout the 1990s, and recent data from the Colorado Insulin Dependent Diabetes Mellitus Registry showed a 2.3% increase per year in incidence of type 1 diabetes over the last two decades (2). The Chicago Childhood Diabetes Registry also reported significant increases in rates of type 2 diabetes among African-American and Latino children during 1985–2001 (3), presumably due to trends in childhood obesity.

Given the increasing numbers of children with diabetes and the considerable morbidity and associated health care expenditures, we wished to evaluate national trends in hospitalizations associated with diabetes for children and young adults. One previous study evaluated trends in hospital discharges associated with diabetes for children from the National Hospital Discharge Survey (7), reporting a prevalence rate of 1.43% during 1979–1981 and 2.36% during 1997–1999. However, that study only included diabetes discharges associated with an obesity diagnosis, which is uncommonly coded, did not evaluate population-adjusted trends for specific age strata, and did not include hospital charge data (7).

We used the Nationwide Inpatient Sample (NIS), a nationally representative annual sample of discharges from nonfederal, short-term, general, and other specialty hospitals in the U.S., to assess trends in hospitalizations and hospital charges associated with a diabetes diagnosis from 1993 to 2004. Based on trends in diabetes reported from previous studies, we hypothesized that there would be increasing prevalence rates of discharges associated with diabetes in children and young adults, with corresponding increases in hospital charges.

We chose to include individuals aged 20–29 years because one study from the 1990s suggested that increases in diabetes among young adults in the U.S. were marked (8). We wished to evaluate trends in diabetes over the early life course, permitting a comparison of trends among children with concurrent trends among young adults.

RESEARCH DESIGN AND METHODS

Data sources

The NIS is a publicly available, deidentified annual database of hospital inpatient stays, sponsored by the Agency for Healthcare Research and Quality (9), which includes data on ICD-9 codes and hospital charges. The NIS represents all discharges from an approximate 20% stratified sample of U.S. community hos-

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Abbreviations: CPI, Consumer Price Index; NIS, Nationwide Inpatient Sample; PPV, positive predictive value.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

pitals, with stratification based on hospital region, urban/rural location, teaching status, number of beds, and ownership. NIS data from 1993 to 2004 were included in this analysis.

Table 1—*Sample characteristics for 1993 and 2004*

	1993	2004
Weighted no. of diabetes discharges (*n* = unweighted)	111,313 (20,867)	166,509 (34,517)
Age-groups		
0–9 years	8.0	7.0
10–14 years	11.9	9.6
15–19 years	16.4	16.6
20–24 years	25.2	28.0
25–29 years	38.6	38.9
Female sex	60.4	62.5
Insurance type		
Medicaid	31.2	37.9
Private	43.3	38.0
Other	25.5	24.2

Data are %.

Study population

We searched for diabetes diagnoses (ICD-9-CM codes 250.xx) in any of 15 diagnostic positions associated with discharges for individuals aged 0–29 years. We considered inclusion of other diagnostic codes including gestational diabetes but chose to focus on the 250.xx diabetes codes alone to make our analysis more comparable with other clinical studies. Codes specific for type 1 diabetes are indicated by a fifth digit of 1 (250.x1) or 3 (250.x3) and for type 2 diabetes are indicated by a fifth digit of 0 (250.x0) or 2 (250.x2). One recent study in children and young adults showed a positive predictive value (PPV) of 97% for type 1 diabetes diagnostic codes but only 16% for type 2 diabetes codes (10) (i.e., whereas 97% of individuals with diagnostic codes for type 1 diabetes had type 1 diabetes verified by medical chart review, only 16% of individuals with diagnostic codes for type 2 diabetes had type 2 diabetes). The low PPV of type 2 diabetes diagnostic codes was mostly due to the misclassification of type 1 for type 2 diabetes. Because 74% of individuals with type 2 diabetes diagnostic codes were verified as having either type 1 or type 2 diabetes (PPV 74%) (10), we evaluated discharges for both types combined. Among females, discharges associated with childbirth were identified using diagnosis-related group codes 370–376 (cesarean/vaginal delivery) and 383 (other antepartum diagnoses with medical complications).

Data analysis

Discharge-level weights for each year were used to estimate national hospitalization rates, total charges, and corresponding SE estimates. To obtain hospitalization rates standardized to the concurrent national population, U.S. Census data for each respective year (1993–2004) were used to calculate rate denominators for the overall population and for sex- and age-stratified analyses. Standardization to the U.S. population with diabetes was not performed, as diabetes prevalence data among individuals 0–29 years for each specific year are unavailable. The SEARCH (Search for Diabetes in Youth) study estimated the prevalence of diabetes among children but only for 2001 (1). Rates of missing data by sex (0%) and insurance type (1.2%) were low, but trends by race/ethnicity could not be determined because of significant missing data (~25%). We were unable to look at trends in age-specific death rates associated with diabetes because of the small number of deaths in age-specific strata.

All analyses were conducted using STATA 9.0, with application of appropriate weights to account for the complex sampling design and to allow for extrapolation to national population estimates. Taylor series linearization was used for variance estimation. All results presented are weighted estimates.

For assessing trends in health care spending by payer type (Medicaid versus private), total hospital charges were estimated for each year using the appropriate discharge weights and standardized to 2004 U.S. dollars using the Consumer Price Index (CPI). We chose to use the overall CPI because of concerns that the medical care CPI does not accurately capture the cost of health care for third-party payers who would be paying the vast majority of claims for hospital services (11). The charge data were analyzed for outliers, and trend analyses were performed after removing the top 1% of total charges, with similar results (data not shown).

Because of the complex survey design of the NIS, sampling weights are changed annually to reflect increases in the number of states participating. Therefore, combining data from each of the 12 years into a single dataset would lead to inaccurate point and variance estimates. To determine whether there were significant increases in hospitalizations and total charges, variance-weighted tests for linear and curvilinear trends were performed, which do not assume homogeneity of variance and incorporate the standard errors of the estimates for each year. To test the hypothesis that the rate of change varied by age, two different variance-weighted least-squares regression models were run: *1)* a model for linear trend, including age-group, year, and the interaction between age-group and year; and *2)* a model for curvilinear trend, including age-group, year squared, and the interaction between age-group and year squared. Similar regression models were run to test for sex-specific differences in rate of change.

RESULTS

— For individuals aged 0–29 years during the years 1993 and 2004, the NIS sample included data for 2,112,556 and 2,305,258 unweighted discharges, respectively, representing 11,143,316 and 11,099,327 discharges annually. Table 1 shows sample characteristics of discharges associated with diabetes by age-group, sex, and insurance type.

Annual rates of hospitalizations associated with diabetes

Figure 1 presents population-adjusted annual rates of hospitalizations associated with diabetes, type 1 and type 2 combined, for individuals aged 0–29 years over the 12-year study period. Overall, there was a 38% increase in the number of population-adjusted hospitalizations associated with diabetes, with 99.1 of

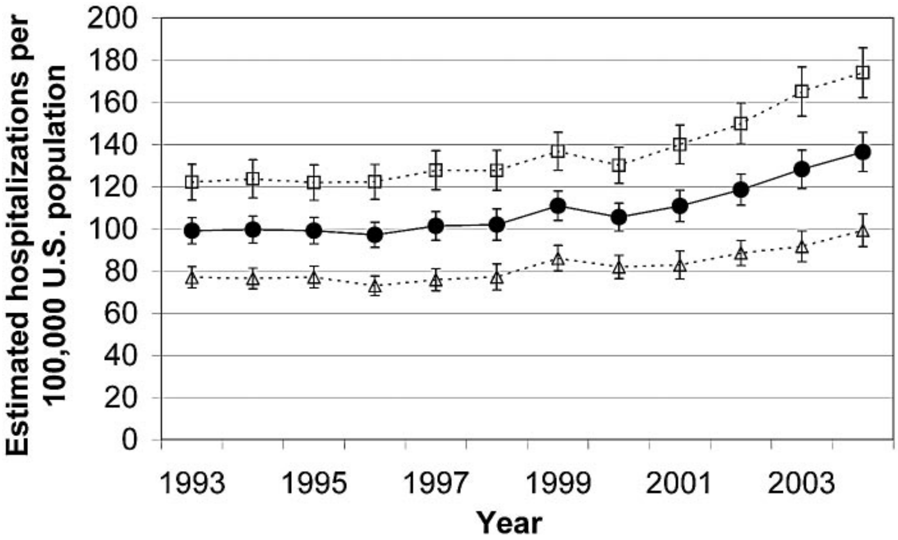

Figure 1—*Estimated annual hospitalizations associated with diabetes (type 1 and type 2 combined) among U.S. children and young adults aged 0–29 years overall and by sex.* ●*, all individuals aged 0–29 years;* □*, females;* ▲*, males. Error bars indicate 95% CI.*

100,000 in 1993 and 136.4 of 100,000 in 2004 ($P < 0.001$ for curvilinear trend).

Age-specific patterns

Figure 2 illustrates the population-adjusted annual rates of hospitalizations associated with diabetes across age strata. There were no significant increases in hospitalization rates for diabetes for children aged <20 years. However, there were significant increases in hospitalizations among individuals aged 20–24 and 25–29 years ($P < 0.001$ for curvilinear trend).

Sex-specific patterns

Sex-specific hospitalization rates, which increased over the 12-year period for both sexes, are also shown in Fig. 1 ($P < 0.001$ for curvilinear trend). Rates of hospitalizations were consistently higher for females than for males throughout the time period (122.1 of 100,000 for females vs. 77.0 of 100,000 for males in 1993 and 174.1 of 100,000 for females vs. 99.3 of 100,000 for males in 2004). Even after removing hospitalizations associated with childbirth, which accounted for ~15% of discharges overall throughout the study period, rates for females remained higher (data not shown). Furthermore, increases in hospitalization rates were significantly greater for females (42%) than for males (29%) ($P < 0.001$).

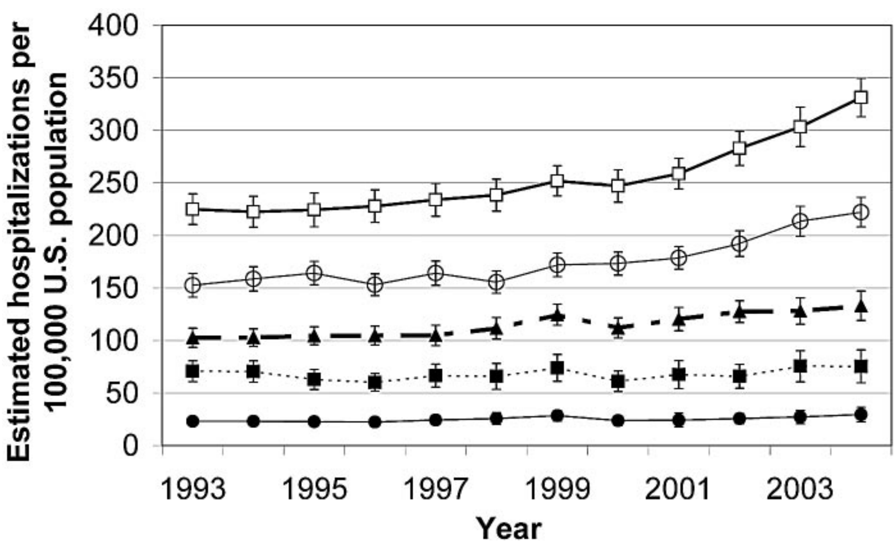

Figure 2—*Estimated annual hospitalizations associated with diabetes (type 1 and type 2 combined) by age strata among U.S. children and young adults aged 0–29 years.* ●*, 0–9 years;* ■*, 10–14 years;* ▲*, 15–19 years;* ○*, 20–24 years;* □*, 25–29 years. Error bars indicate 95% CI.*

Concurrent increases in hospital charges

Inflation-adjusted annual aggregate hospital charges for diabetes over the study period increased 130%, from $1.05 billion in 1993 to $2.42 billion in 2004, with significant increases in total charges for Medicaid and private payers ($P < 0.001$ for curvilinear trend). Figure 3 illustrates the proportion of total charges by Medicaid, private insurers, and "other" insurance category (including uninsured) for each year. In 2004, aggregate estimated hospital charges were $924 million for Medicaid and $849 million for private payers.

CONCLUSIONS

— This is the first analysis of which we are aware to use nationally representative hospital discharge data to document statistically significant increasing prevalence rates of hospitalizations and associated hospital charges for individuals with diabetes aged 0–29 years over a recent 12-year period. Strengths of this study include the representative nature of the NIS with sample sizes large enough to examine year-to-year trends in hospitalizations, the time period covering over a decade, and the inclusion of individuals over the early life course, from childhood through young adulthood.

We found significant increases in population-adjusted hospitalization rates among individuals aged 0–29 years overall, but the increases were chiefly attributable to significant increases in annual hospitalization rates among young adults aged 20–29 years. Given that type 2 diabetes accounts for 90–95% of incident cases in adulthood (12), the increase in young adults is consistent with an increase in the prevalence of type 2 diabetes. We speculate that this increase in diabetes among young adults reflects the growing prevalence of childhood obesity in the U.S. and the physiological connection between obesity and type 2 diabetes.

Obesity is the hypothesized critical risk factor contributing to the elevated risk of type 2 diabetes in individuals (13). Although severity of obesity is an important risk factor for development of type 2 diabetes (14), duration of obesity is also a critical risk factor, with studies showing higher incidence rates of diabetes in indi-

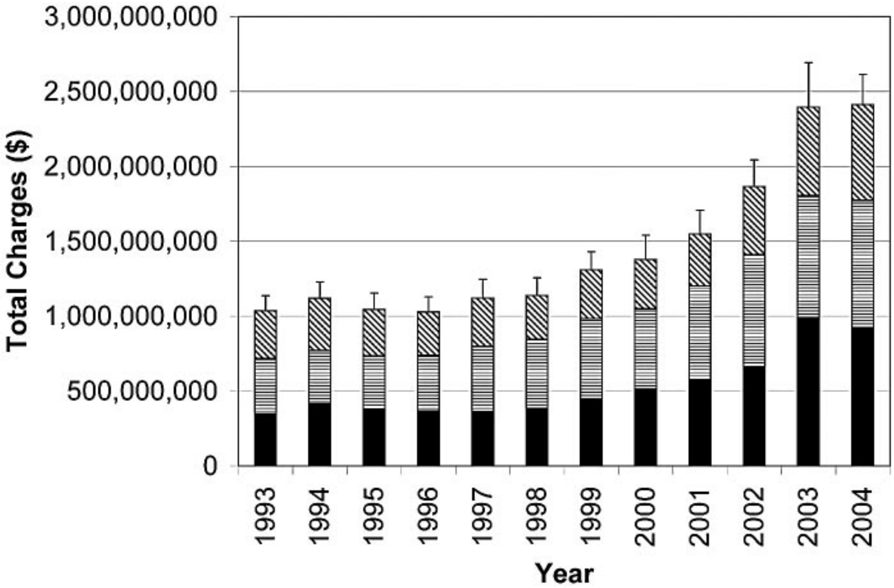

Figure 3—*Estimated total charges associated with hospitalizations for diabetes among children and young adults aged 0–29 years by payer type.* ■*, Medicaid;* ▤*, private payers;* ▧*, other payers. Error bars indicate 95% CI.*

viduals with a longer duration of obesity.(15,16) Because progression from obesity to development of type 2 diabetes is hypothesized to occur over a period of several years (17), latency between the development of obesity in childhood and the onset of clinically diagnosed type 2 diabetes years later could contribute to the increase in hospitalization rates in young adulthood observed in these data.

Specifically, we found increases in hospitalizations among young adults occurring after the year 2000. Individuals aged 20–29 years after 2000 represent a birth cohort who experienced childhood and adolescence in the late 1970s and early 1980s, at the leading edge of the childhood obesity epidemic (18). Therefore, the cohort effects of childhood obesity from the 1970s to the 1980s could be presenting just now as the first manifestation of a related "diabetes epidemic" among young adults. Other studies may more precisely elucidate the impact of childhood obesity on type 2 diabetes rates in young adults and how the changing dynamics of obesity in children will affect future type 2 diabetes rates in the U.S. population. Of great concern are the facts that studies have documented that the prevalence of obesity among U.S. children has doubled over the last two decades (18), obesity onset is occurring at younger ages (18), and the severity of obesity in children has increased over time (19). Therefore, further increases in rates of type 2 diabetes among young adults, beyond what is evident by 2004, appear very likely and perhaps inevitable.

Contrary to our hypothesis, increases in diabetes were not observed for the pediatric age strata. We know of one other study in which trends in diabetes prevalence among children were evaluated on the basis of diagnostic codes from outpatient as well as inpatient claims data (20). In contrast to the findings of our study, that analysis showed significant increases in diabetes rates, in particular type 1 diabetes. Because the NIS tracks inpatient hospitalizations and not outpatient visits, our study may have underestimated trends in diabetes, given that an increasing number of children with new-onset type 1 diabetes are no longer admitted to the hospital but are managed as outpatients and that individuals who present with new-onset type 2 diabetes may present less often with ketosis compared with individuals with new-onset type 1 diabetes and can often be managed initially with lifestyle management and oral medications as outpatients.

Nevertheless, our study is the first to document increasing trends in aggregate national hospital charges for diabetes among children and young adults. Previous studies have evaluated hospitalizations and costs primarily for older adults (21), and one pediatric study did not evaluate total hospital charges but rather applied a standard average hospital cost multiplied by the number of diabetes discharges (7). We found evidence of increasing trends in hospital charges for both Medicaid and private insurers, approaching $1 billion in annual charges for each group. With the continuing epidemic of childhood obesity and increasing trends in type 2 diabetes among young adults, the economic burden attributable to diabetes will probably continue to rise, affecting public and private insurance plans alike. This economic reality may serve as a critical impetus for payers to consider covering services that may reduce or otherwise address obesity among their younger enrollees before the onset of diabetes and related hospitalizations.

Our finding of higher rates of hospitalizations among females than among males, even after exclusion of childbirth-related discharges, is consistent with previous studies of state-based discharge data from California (22) and North Carolina (23), which also documented similar sex differences in hospital discharges. This finding may be related to the higher prevalence (1) and incidence (4) of diabetes in U.S. females versus males. Our study is unique in that we found a larger rate of increase in diabetes hospitalizations for females (42%) than for males (29%) over the 12-year period. We speculate that larger increases among females over this period may be related to greater morbidity, as one recent U.S. study reported a doubling of all-cause mortality among adult females with diabetes between 1971 and 2000, in contrast with a 43% decrease in all-cause mortality in adult males with diabetes (24). However, that study reported mortality only among individuals with diabetes who were ≥35 years (24), suggesting the need for further studies to better understand sex differences in diabetes hospitalization rates for younger individuals.

Limitations

There are limitations to our study. Discharges associated with diabetes do not necessarily represent a new diagnosis of diabetes but may represent multiple repeat hospitalizations for individuals, which could lead to overestimates of the trends in diabetes based on hospital discharges. However, the fact that the likelihood of hospitalizations for diabetes has decreased over the study period due to changes in clinical practice means that observed increases in hospitalization rates are all the more remarkable.

Type 2 diabetes has received greater attention during the study period, which may have led to increased provider awareness of diabetes and a higher likelihood of documenting diabetes diagnoses associated with hospital discharges over time. Furthermore, the proportion of undiagnosed to diagnosed diabetes has decreased over time (25), and the definition of diabetes based on fasting plasma glucose was lowered to 126 mg/dl in 1997, leading to possible year-specific biases in estimation of diabetes trends. Increases in diabetes hospitalizations may also be due to an increased burden of type 1 rather than type 2 diabetes, as some studies have shown increases in the incidence of type 1 diabetes (2,6). Finally, rates of discharges associated with diabetes in states who participated in the NIS may have been different from those of states that did not participate.

Implications

Increasing rates of hospitalizations and associated expenditures among young adults with diabetes over the last decade suggest the need for further studies to examine trends in diabetes prevalence among young adults and to understand how the childhood obesity epidemic in the U.S. may further amplify these trends. Increases in hospitalizations and expenditures may present third-party payers with a strong impetus to cover services that address prevention and treatment of obesity in younger generations.

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References

1. Liese AD, D'Agostino RB Jr, Hamman RF, Kilgo PD, Lawrence JM, Liu LL, Loots B, Linder B, Marcovina S, Rodriguez B, Standiford D, Williams DE: The burden of diabetes mellitus among US youth: prevalence estimates from the SEARCH for Diabetes in Youth Study. *Pediatrics* 118:1510–1518, 2006
2. Vehik K, Hamman RF, Lezotte D, Norris JM, Klingensmith G, Bloch C, Rewers M, Dabelea D: Increasing incidence of type 1 diabetes in 0- to 17-year-old Colorado youth. *Diabetes Care* 30:503–509, 2007
3. Lipton RB, Drum M, Burnet D, Rich B, Cooper A, Baumann E, Hagopian W: Obesity at the onset of diabetes in an ethnically diverse population of children: what does it mean for epidemiologists and clinicians? *Pediatrics* 115:e553–e560, 2005
4. Dabelea D, Bell RA, D'Agostino RB Jr, Imperatore G, Johansen JM, Linder B, Liu LL, Loots B, Marcovina S, Mayer-Davis EJ, Pettitt DJ, Waitzfelder B: Incidence of diabetes in youth in the United States. *JAMA* 297:2716–2724, 2007
5. Lipman TH, Chang Y, Murphy KM: The epidemiology of type 1 diabetes in children in Philadelphia 1990–1994: evidence of an epidemic. *Diabetes Care* 25: 1969–1975, 2002
6. Libman I: Was there an epidemic of diabetes in non-white adolescents in Allegheny County, Pennsylvania. *Diabetes Care* 21:1278–1281, 1998
7. Wang G, Dietz WH: Economic burden of obesity in youths aged 6 to 17 years: 1979–1999. *Pediatrics* 109:e81–e81, 2002
8. Mokdad AH, Ford ES, Bowman BA, Nelson DE, Engelgau MM, Vinicor F, Marks JS: Diabetes trends in the U.S.: 1990–1998. *Diabetes Care* 23:1278–1283,2000
9. Health Care Cost and Utilization in Project (HCUP): *Nationwide Inpatient Sample (NIS)*. Rockville, MD, Agency for Healthcare Research and Quality, 2003
10. Rhodes ET, Laffel LM, Gonzalez TV, Ludwig DS: Accuracy of administrative coding for type 2 diabetes in children, adolescents, and young adults. *Diabetes Care* 30:141–143, 2007
11. *Consumer Price Index: Cost-of-Living Concepts and the Housing and Medical Care Components*. Washington, DC, Government Accounting Office, 1996
12. Engelgau MM, Geiss LS, Saaddine JB, Boyle JP, Benjamin SM, Gregg EW, Tierney EF, Rios-Burrows N, Mokdad AH, Ford ES, Imperatore G, Narayan KM: The evolving diabetes burden in the United States. *Ann Intern Med* 140:945–950, 2004
13. Knowler WC, Pettitt DJ, Saad MF, Charles MA, Nelson RG, Howard BV, Bennett PH: Obesity in the Pima Indians: its magnitude and relationship with diabetes. *Am J Clin Nutr* 53 (Suppl. 6):1543S–1551S, 1991
14. Fox CS, Pencina MJ, Meigs JB, Vasan RS, Levitzky YS, D'Agostino RB Sr: Trends in the incidence of type 2 diabetes mellitus from the 1970s to the 1990s: the Framingham Heart Study. *Circulation* 113: 2914–2918, 2006
15. Everhart JE: Duration of obesity increases the incidence of NIDDM. *Diabetes* 41:235–240, 1992
16. Wannamethee SG, Shaper AG: Weight change and duration of overweight and obesity in the incidence of type 2 diabetes. *Diabetes Care* 22:1266–1272, 1999
17. Mokdad AH, Ford ES, Bowman BA, Nelson DE, Engelgau MM, Vinicor F, Marks JS: The continuing increase of diabetes in the U.S. *Diabetes Care* 24:412, 2001
18. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM: Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 295: 1549–1555, 2006
19. Jolliffe D: Extent of overweight among US children and adolescents from 1971 to 2000. *Int J Obes* 28:4–9, 2004
20. Kemper AR, Dombkowski KJ, Menon RK, Davis MM: Trends in diabetes mellitus among privately insured children, 1998–2002. *Ambul Pediatr* 6:178–181, 2006
21. Aubert RE, Geiss LS, Ballard DJ, Cocanougher B, Herman WH: Diabetes-related hospitalization and hospital utilization. In *Diabetes in America*. 2nd ed. Bethesda, MD, National Institute of Diabetes and Digestive and Kidney Diseases, 1995, p. 553–569
22. California Department of Health Services: *Diabetes and Diabetic Complications: Deaths and Hospitalizations in California, 1983–1987*. Sacramento, CA, California Chronic and Sentinel Diseases Surveillance Program, 1992 (Tech. rep. no. 9)
23. North Carolina Department of Environment, Health, and Natural Resources: *Diabetes Surveillance in North Carolina Final Evaluation Report, FY90-FY93*. Raleigh, NC, State Center for Health and Environmental Statistics, 1993
24. Gregg EW, Gu Q, Cheng YJ, Narayan KM, Cowie CC: Mortality trends in men and women with Diabetes, 1971–2000. *Ann Intern Med* 147:149–155, 2007
25. Gregg EW, Cadwell BL, Cheng YJ, Cowie CC, Williams DE, Geiss L, Engelgau MM, Vinicor F: Trends in the prevalence and ratio of diagnosed to undiagnosed diabetes according to obesity levels in the U.S. *Diabetes Care* 27:2806–2812, 2004