Changes in Incidence of Diabetes in U.S. Adults, 1997–2003

Linda S. Geiss, MA, Liping Pan, MD, MPH, Betsy Cadwell, MSPH, Edward W. Gregg, PhD, Stephanie M. Benjamin, PhD, Michael M. Engelgau, MD, MPH

Background: The incidence of self-reported diagnosed diabetes may be increasing because of recent changes in the diagnostic criteria for diabetes, enhanced case detection, and a true increase in disease incidence. These factors may also be changing the characteristics of newly diagnosed cases. Therefore, we examined recent trends in the incidence of diagnosed diabetes, changes to the characteristics of incident cases, and factors associated with incidence.

Methods: First, National Health Interview Survey data for 1997 to 2003 were used to examine 7-year trends in the incidence of diagnosed diabetes among U.S. adults aged 18 to 79 years. Second, among 1997–1998 and 2002–2003 incident cases, differences in sociodemographic characteristics, risk factors, and indicators of health status were examined. Lastly, multivariate-adjusted incidence from multiple logistic regression of 2001–2003 survey data were derived.

Results: From 1997 to 2003, the incidence of diagnosed diabetes increased 41% from 4.9 to 6.9 per 1000 population ($p<0.01$). Incidence increased among men and women, non-Hispanic whites, persons with at least a high school education, nonsmokers, active and inactive persons, and among obese persons ($p<0.05$). Obesity was more prevalent ($p<0.01$) and physical limitation was less prevalent ($p=0.03$) in 2002–2003 versus 1997–1998 incident cases. Multivariate-adjusted incidence increased with age and BMI category, and decreased with education level ($p<0.05$).

Conclusions: Obesity was a major factor in the recent increase of newly diagnosed diabetes. Lifestyle interventions that reduce or prevent the prevalence of obesity among persons at risk for diabetes are needed to halt the increasing incidence of diabetes.

(Am J Prev Med 2006;30(5):371–377) © 2006 American Journal of Preventive Medicine

Introduction

Recent national survey data indicate that the prevalence and incidence of self-reported diagnosed diabetes is increasing in the United States.[1] These trends could be a function of several major factors, including recent changes to the diagnostic criteria for diabetes,[2] enhanced case detection, increasing survival among prevalent cases, change in demographics of the U.S. population, and a true increase in disease incidence. Each of these factors could change the characteristics of incident cases and eventually change the characteristics of the population of people with diagnosed diabetes. Although the probable impact of new diagnostic criteria on the phenotype of incident cases in the United States has not been well studied, a recent European study suggested that shifting from oral glucose tolerance tests to fasting glucose tests to diagnose diabetes may be more likely to diagnose diabetes in younger people and those who are obese.[3] Similarly, enhanced case detection could yield a healthier and younger diabetic population by detecting diabetes among younger people and earlier in the course of their disease, before complications develop. In addition, obesity, a major risk factor for diabetes, is increasing in the United States,[4,5] and could result in a true increase in diabetes incidence, as well as an increase in the number of incident cases who are obese. Further, the prevalence of obesity in incident cases may have increased if, as a recent study suggests, enhanced detection of diabetes is occurring in the most obese individuals (those with a body mass index [BMI] of 35 kg/m^2 or more).[6]

Limitations of national surveillance systems prevent the examination of whether true incidence has changed, as this would require repeated physiological

From the Division of Diabetes Translation, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia

Address correspondence and reprint requests to: Linda S. Geiss, MA, Division of Diabetes Translation, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, Mailstop K-10, Atlanta GA 30341. E-mail: LGeiss@cdc.gov.

The full text of this article is available via AJPM Online at www.ajpm_online.net.

0749-3797/06/$–see front matter
doi:10.1016/j.amepre.2005.12.009

measures on a national representative sample. However, closer examination of whether the characteristics of newly diagnosed cases of diabetes have changed could provide additional clues to the factors most responsible for the diabetes epidemic, while at the same time providing information to public health decision makers to help them effectively manage the growing population with diabetes. Thus, the purpose of this study was to use nationally representative data to examine recent trends in the incidence of self-reported diagnosed diabetes and whether the characteristics of incident cases have changed. Factors associated with the incidence of diagnosed diabetes among U.S. adults were also identified.

Methods

Data from the National Health Interview Survey (NHIS) in 1997 through 2003 of the National Center for Health Statistics, Centers for Disease Control and Prevention, were used to perform the analyses. Using a multistage cluster sample design, the NHIS surveys the non-institutionalized, civilian U.S. population each year to provide health and risk factor information.[7] A major redesign of NHIS implemented in 1997 resulted in a sufficient sample size for annual estimates of diabetes incidence.

All sampled adults (approximately 31,000 annually) are asked whether a health professional had ever told them they had diabetes. To exclude gestational diabetes, the NHIS asks women whether they had been told they had diabetes other than during pregnancy. Respondents reporting a diagnosis of diabetes (approximately 2000 annually) are asked how old they were when diabetes was diagnosed. The number of years each person had diagnosed diabetes was calculated by subtracting their age at diagnosis from their age at the time of the interview. A value of 0 indicated that the disease was diagnosed within the previous year. Using this method, people who had a birthday during their first year of diabetes would be misclassified. To account for this, it was assumed that half of those with a value of 1 also had the disease diagnosed within the previous year. The incidence of diagnosed diabetes was calculated using the number of adults who were diagnosed with diabetes within the past year as the numerator and the entire adult population, excluding those who had been previously diagnosed with diabetes, as the denominator.

Because NHIS does not collect age at diagnosis for people aged ≤17 years and because privacy protection concerns limited the data available for those aged ≥80, analyses are restricted to people aged 18 to 79 years. All estimates are based on self-reports of survey participants and are weighted to reflect the age, gender, and racial/ethnic distribution of the adult, non-institutionalized U.S. population. All analyses were conducted in 2005 with the use of SUDAAN, version 9.0.1 (Research Triangle Institute, Research Triangle Park NC, 2004), and the 2000 U.S. population was used as the standard population for age adjustment. Age-adjusted trends in incidence were examined by gender; race/ethnicity; BMI category (based on height and weight: normal [BMI <25 kg/m^2]; overweight [BMI ≥ 25 to <30 kg/m^2]; and obese [BMI ≥ 30 kg/m^2]); education level (less than high school, high school, more than high school); smoking status (current smokers versus non–current smokers); and physical inactivity (not active vs active in leisure activity). Annual age-specific and age-adjusted estimates of incidence for each of the years were calculated and trends over the 7-year period were tested using linear regression, weighting the annual estimates by the inverse of their variances.

To examine changes to the characteristics of incident cases, the analytic sample was restricted to the earliest 2 years and the most recent 2 years. T-tests and chi-squared tests were used to examine differences between 1997–1998 incident cases and 2002–2003 incident cases by age; gender; race/ethnicity; BMI category; education; smoking status; physical inactivity status; and indicators of health status, including self-assessment of health status (poor to fair versus good to excellent); self-reported hypertension (had been told they had hypertension at least twice); coronary heart disease (had ever been told they had coronary heart disease, angina, or heart attack); stroke (had ever been told they had a stroke); and difficulty in performing any of nine physical functions (i.e., walking a quarter mile, walking up ten steps without rest, standing for 2 hours, sitting for 2 hours, stooping, reaching overhead, grasping with fingers, lifting or carrying 10 pounds, pushing or pulling large objects, and stooping).

Finally, the analytic sample was restricted to the most recent 3 years (2001–2003) to perform multiple logistic regression to model incidence by gender, age, race/ethnicity, BMI category, education level, smoking status, and physical inactivity status. Before building the final regression model, the main effects were examined to eliminate nonsignificant predictors (i.e., gender, smoking status, and physical inactivity status) and then all two-way interaction terms were added. Backward selection was used to obtain the best model. Next, predictive margins were calculated based on the final model, which consisted of age, race/ethnicity, BMI category, education level, and the interaction between age and BMI category. Predictive margins are a type of direct standardization in which the predicted values from the logistic regression model are averaged over the covariate distribution of the population.[8]

Results

Trends from 1997 to 2003

From 1997 to 2003, the incidence of self-reported diagnosed diabetes increased 41%, from 4.9 to 6.9 per 1000 population ($p<0.01$ for linear trend) (Figure 1). This increase was only slightly greater than the 37% increase in age-adjusted incidence, from 5.2 per 1000 in 1997 to 7.1 per 1000 in 2003 ($p<0.01$). Throughout the time period, incidence was strongly associated with age and tended to increase over time in each age group. From 1997 to 2003, incidence increased from 2.1 to 2.5 per 1000 ($p=0.06$) among people aged 18 to 44 years; increased from 8.6 to 11.2 per 1000 ($p=0.04$) among those aged 45 to 64 years; and increased from 10.2 to 16.8 per 1000 ($p=0.04$) among those aged 65 to 79 years.

Age-adjusted incidence was higher in 2003 than in 1997 for all demographic subgroups and risk factors,

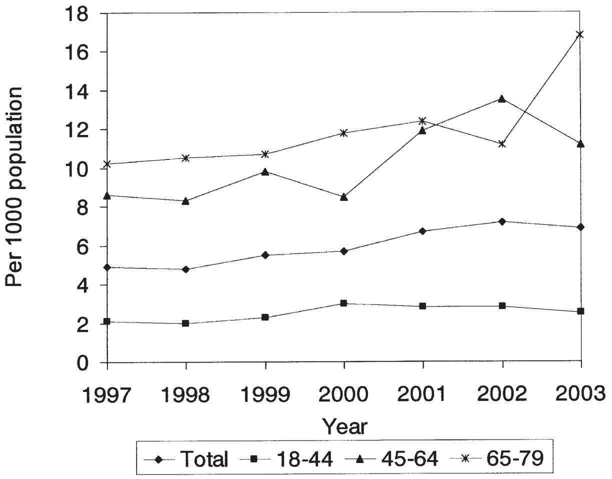

Figure 1. Incidence of self-reported diagnosed diabetes, by age, United States, 1997–2003.

with linear trends significant among men (p =0.01) and women (p =0.05), non-Hispanic whites (p <0.01), people with a high school education (p=0.01) and more than high school education (p =0.04), nonsmokers (p =0.03), the physically active (p =0.04) and inactive (p <0.01), and among obese people (p =0.02) (Table 1). In 2003, about 89% of all incident cases were either overweight or obese (30% and 59%, respectively).

Characteristics and Health Status of 1997–1998 Versus 2002–2003 Incident Cases

Mean age at diagnosis among incident cases identified in 1997–1998 (53.7 years) did not significantly differ from those identified in 2002–2003 (53.4 years), nor did the distribution of incident cases differ in terms of gender, race/ethnicity, education level, smoking status, and physical inactivity status (Figure 2). However, the prevalence of obesity was higher among 2002–2003 incident cases (59.7%, 95% confidence interval [CI]=54.6%–64.8%) than among 1997–1998 incident

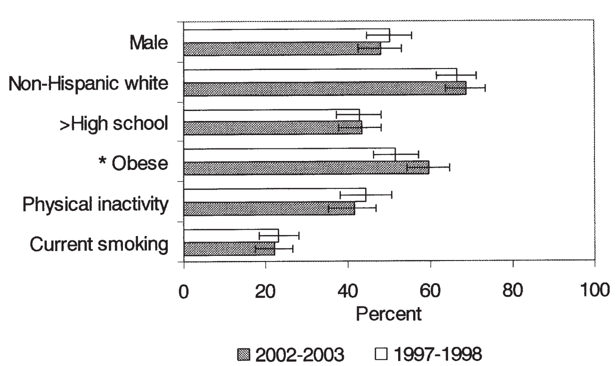

Figure 2. Characteristics of 1997–1998 and 2002–2003 incident cases of self-reported diagnosed diabetes. *Difference between 1997–1998 and 2002–2003, p <0.05.

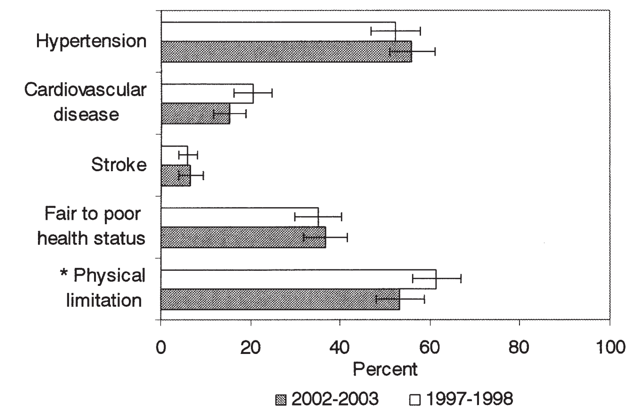

Figure 3. Health status of 1997–1998 and 2002–2003 incident cases of self-reported diagnosed diabetes. *Difference between 1997–1998 and 2002–2003, p <0.05.

cases (51.6%, 95% CI=46.1%–57.0%) (p <0.01). In this time period, the prevalence of obesity also increased among those without diabetes, from 18.6% (95% CI=18.3–19.0) to 22.0% (95% CI=21.6–22.5).

With the exception of physical limitation, there were no significant differences between the two time periods in the self-reported prevalence of health status indicators, including hypertension, coronary heart disease, stroke, or poor or fair health status (Figure 3). The prevalence of any physical limitation declined from 61.5% (95% CI=56.2%–66.8%) in 1997–1998 to 53.4% (95% CI=48.1%–58.6%) in 2002–2003 incident cases. However, the prevalence of any physical limitation also declined among adults without diabetes (p <0.01), from 29.2% (95% CI=28.7%–29.7%) in 1997–1998 to 24.5% (95% CI=24.0%–25.0%) in 2002–2003.

Multivariate-Adjusted Incidence in 2001–2003

In a multivariate analysis of 2001–2003 data using age, gender, race/ethnicity, BMI category, education level, income level, current smoking status, and physical inactivity status to model incidence, gender, smoking status, and physical inactivity status were not significant predictors. Age, race/ethnicity, BMI category, and education level were significant predictors in the final model, and there was a significant interaction between BMI category and age (Table 2). This interaction resulted from the BMI category having less of an impact on incidence among those aged 18 to 44 years compared to those who were older.

The multivariate-adjusted incidence among persons aged 18 to 44 years (2.9 per 1000) was much lower than among those older (>11 per 1000). By racial/ethnic group, adjusted incidence was lowest among non-Hispanic whites (6.3 per 1000) and highest among non-Hispanic blacks (8.2 per 1000) and other race/ethnicities (14.7 per 1000). As educational level increased, multivariate-adjusted incidence decreased from 9.7 per 1000 among people with less than a high

Table 1. Age-adjusted incidence of self-reported diagnosed diabetes

	1997 incidence		2003 incidence			*p* value for linear trend, 1997–2003
	Per 1000	95% CI	Per 1000	95% CI	Number of new cases in 1000s[a]	
Total	5.2	(4.4–6.0)	7.1	(6.0–8.1)	1330	**<0.01****
Gender						
Male	4.8	(3.5–6.1)	7.2	(5.6–8.8)	622	**0.01***
Female	5.5	(4.5–6.6)	7.1	(5.7–8.4)	707	0.05
Race/ethnicity						
NH white	4.5	(3.6–5.4)	6.6	(5.4–7.8)	951	**<0.01****
NH black	9.1	(6.4–11.9)	9.9	(6.4–13.4)	183	0.12
Hispanic	6.6	(4.1–9.2)	9.1	(6.1–12.2)	166	0.09
Other	NR		NR		NR	
BMI category				[b]		
Normal	1.5	(0.9–2.1)	2.0	(0.9–3.1)	131	0.24
Overweight	4.7	(3.5–5.9)	5.5	(4.1–7.0)	382	0.13
Obese	14.2	(11.2–17.2)	18.3	(14.9–21.6)	751	**0.02***
Education level				[b]		
< High school	8.6	(5.8–11.4)	9.8	(7.0–12.6)	295	0.10
High school	4.3	(3.1–5.6)	7.5	(5.6–9.4)	435	**0.01***
> High school	4.5	(3.5–5.6)	6.2	(4.7–7.7)	590	**0.04***
Current smoking						
Smoker	4.6	(2.9–6.2)	9.1	(6.3–12.0)	346	0.09
Nonsmoker	5.3	(4.4–6.3)	6.6	(5.5–7.7)	980	**0.03***
Physical inactivity				[c]		
Yes	7.8	(5.2–10.4)	8.8	(6.9–10.7)	563	**0.04***
No	3.4	(2.5–4.3)	6.1	(4.8–7.4)	704	**<0.01****

[a]Subgroups may not sum to total because of missing values.
[b]Trend test across categories, $p < 0.05$.
[c]Yes vs no, $p < 0.05$.
*$p < 0.05$.
**$p < 0.01$ (all bolded).
CI, confidence interval; NH, non-Hispanic; NR, estimate is not reliable.

school education to 5.6 per 1000 among those with more than a high school education. Multivariate-adjusted incidence increased sharply with BMI category, ranging from 1.9 per 1000 among normal-weight people to 17.8 per 1000 among the obese.

Conclusion

Among U.S. adults aged 18 to 79 years, the incidence of diagnosed diabetes increased 41% from 1997 to 2003. During this period of rapid change, incidence increased at a greater rate among obese people, resulting in obesity being more prevalent among incident cases at the end of the time period than at the beginning. In a multivariate analysis of 2001–2003 incidence, obese adults had the highest multivariate-adjusted incidence, and overweight and obesity had a stronger association with diabetes among older adults. Altogether, these data suggest that obesity is a large factor—although not the sole factor—in the increasing incidence of diagnosed diabetes. This finding is consistent with previous studies which have shown that diabetes incidence is increasing[9–12] and that a high BMI is an important predictor of diabetes incidence.[9,12–19] It is also consistent with a study of Rochester MN residents, which showed that the BMI of diabetes patients increased between 1970 and 1989.[20]

A recent study of U.S. trends in diabetes prevalence suggested that enhanced case detection may be occurring among extremely obese people (BMI ≥35), but not among those in lower BMI groups.[6] Although the current study did not distinguish between obesity and extreme obesity because of the small number of incident cases, incidence increased among obese people but did not increase significantly in lower BMI groups. Although this finding is consistent with enhanced detection among obese people, the adoption of new diagnostic criteria for diabetes also could have led to a differential diagnosis of diabetes among the obese. Although the impact of new diagnostic criteria on the phenotype of incident cases has not been well studied, a recent European study of the impact suggested that shifting from oral glucose tolerance tests to fasting glucose tests to diagnose diabetes may preferentially diagnose younger and obese people.[3] Consistent with this suggestion, in the current study, was a significant increase among obese people but not among people in other BMI categories. Inconsistent with this suggestion, the largest relative increase in age-specific incidence (a 65% increase) in the current study was in people aged

65 to 79 years. However, if oral glucose tolerance tests were rarely used for diabetes diagnosis before the recent change in diagnostic criteria, then the new criteria's de-emphasis of the use oral glucose tolerance tests would have less of an impact than lowering the fasting glucose levels from 140 and higher to 126 and higher mg/dL. Unfortunately, little is known about what physicians actually use to diagnose diabetes and whether this has changed over time.

Age-adjusted and age-specific incidences were higher in 2003 than in 1997 for most sociodemographic and risk factor subgroups. Although age-adjusted incidence increased in all racial/ethnic groups, the increase was significant only among non-Hispanic whites. The inability to detect significant increases among other racial/ethnic groups may have been due to the small number of incident cases and the limited number of years analyzed. Consistent with the known higher prevalence of diabetes among minority groups, multivariate-adjusted incidence was lowest among non-Hispanic whites and generally higher in other racial/ethnic groups. Because incidence increased in most subgroups, the only significant sociodemographic and risk factor difference among incident cases at the beginning and end of the time period was a significant increase in the percent obese. Additional years of data may be needed before other, less dramatic changes to the phenotype of incident cases can be detected.

When the health status of 1997–1998 incident cases was compared to the health status of 2002–2003 incident cases, no significant differences were found in the prevalence of self-reported hypertension, coronary heart disease, stroke, or poor or fair health status. The only significant difference between the two groups was a lower prevalence of any physical limitation among incident cases identified in the latter time period. This suggests that from 1997 to 2003—a period in which diabetes incidence increased by 41%—incident cases did not become remarkably healthier or younger, which one might have expected if the increased incidence were largely the product of improved diabetes detection. Instead, changes in the profile of incident cases—greater obesity and less physical limitation—mirrored the changes in the U.S. population. Furthermore, over the last few decades, the health of the U.S. population has improved, as evidenced by increases in life expectancy,[21] reductions in cardiovascular risk factors,[22] and declines in cardiovascular disease death rates.[23] Given that newly diagnosed diabetes patients arise out of an increasingly healthier population, improvements over time in the health status of diabetes incident cases might be expected.

In the multivariate model of 2001—2003 incidence, in addition to BMI category and the BMI category—age interaction, age, race/ethnicity, and education level were identified as significant predictors of incidence. These findings are consistent with those of numerous other studies finding incidence associated with age[10,12,13,15,24,25] and race/ethnicity.[16,26,27] In general, these studies found incidence to be higher among older people and members of minority groups. Although the association between educational level and diabetes incidence has not been well studied, similar to results reported here, incidence has generally been shown to be higher among people with less education.[12,27] In a post-hoc, multivariate analysis that examined whether a variable for period (2001–2003 vs 1997–1999) interacted with any of the variables used in the final model, no interactions were found, suggesting that the associations of these variables with incidence did not change over time.

Unlike previous studies,[17,19,25] however, there was no association between physical inactivity and diabetes incidence in the multivariate model. This may be due to the crude measurement of physical inactivity, which did not account for differences in activity levels or types of physical activity, energy expenditure, the slight change in questions during the first year of the survey, the nonprospective nature of the current study, or other methodologic differences.

Prospective population-based studies that include diagnostic tests for diabetes are able to identify new cases of both diagnosed and undiagnosed disease. However, these types of prospective population-based studies are rare and have been conducted on populations not representative of the U.S. population, such as the Pima Indians[24] and participants in the San Antonio Heart Study.[10]

Most incidence studies use cross-sectional survey data, medical records, registries, claims data, and other types of administrative data that can identify only newly diagnosed cases of disease. For example, if a case has not been diagnosed, it can not be counted or identified as a new case. Thus, by not taking into account undiagnosed disease, the current study underestimates diabetes incidence and can not determine the extent to which increased detection may be affecting trends in diabetes incidence. For this reason, it is important for ongoing or future population-based studies to examine changes in the incidence of diagnosed and undiagnosed diabetes combined.

There are at least four other limitations to this study. First, incidence was estimated from age at diagnosis. However, in the 1999 survey, NHIS respondents with diabetes were asked if they had been diagnosed with diabetes in the previous year. Incidence derived from this question did not differ significantly from the estimate calculated from age at diagnosis. Second, because the health status indicators were based on self-reports rather objective measurements, the prevalence of these indicators may also be underestimated. Third, although diabetes incidence was calculated from large, nationally representative surveys, diabetes incidence is a rare event,

Table 2. Multivariate-adjusted incidence of self-reported diagnosed diabetes

	Predictive margins for 2001–2003 incidence	
	Per 1000	**95% CI**
Age group[a]		
18–44	2.9 (Ref)	(2.4–3.4)
45–64	**11.1***	(9.8–12.4)
≥65	**13.0***	(11.0–15.1)
Race/ethnicity		
NH white	6.3 (Ref)	(5.6–7.0)
NH black	**8.2***	(6.6–9.9)
Hispanic	7.3	(5.8–8.9)
Other	**14.7***	(9.1–20.2)
BMI[a]		
Normal	1.9 (Ref)	(1.4–2.5)
Overweight	**5.0***	(4.3–5.8)
Obese	**17.8***	(15.9–19.7)
Education level		
< High school	9.7 (Ref)	(8.1–11.3)
High school	**7.3***	(6.3–8.4)
> High school	**5.6***	(4.8–6.3)

[a]There was an interaction between age group and BMI category with BMI category having less of an impact on incidence among those aged 18–44 years compared to those older.
*Significantly different with reference group at $p < 0.05$ (bolded).
BMI, body mass index; CI, confidence interval; NH, non-Hispanic; Ref, reference.

and there may have been insufficient power to detect some subgroup differences and trends over time. In addition, the restricted number of years for which the data are available may have limited the ability to detect trends. Finally, incidence and factors associated with incidence could not be examined by type of diabetes and may vary by type of diabetes. Since the vast majority of people with diabetes have type 2, the results presented are more representative of the incidence of type 2 diabetes. Despite these limitations, the findings of the current study are congruent with previous research that has shown diabetes incidence to be increasing, identified obesity as a major—although not sole—risk factor for diabetes, and found age, BMI category, race/ethnicity, and education level to be associated with diabetes risk.

Public Health Implications

Between 1997 and 2003, the incidence of diagnosed diabetes among U.S. adults increased at a rapid rate. This increase was not accompanied by large improvements in the health status of incident cases. The presented data suggest that obesity is a major factor in increasing incidence and that incident cases of diabetes are becoming more obese. Recent clinical trials have found that lifestyle changes that include moderate weight loss and exercise can prevent or delay the onset of diabetes among high-risk adults.[28–30] The development and delivery of lifestyle interventions to people at risk for diabetes are needed to halt the increasing incidence of diabetes.

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the funding agency.

No financial conflict of interest was reported by the authors of this paper.

References

1. Centers for Disease Control and Prevention. National Diabetes Surveillance System. Available at: www.cdc.gov/diabetes/statistics/index.htm. Accessed June 21, 2005.
2. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Diabetes Care 1997;20:1183–97.
3. DECODE Study Group on behalf of the European Diabetes Epidemiology Study Group. Will new diagnostic criteria for diabetes mellitus change phenotype of patients with diabetes? Reanalysis of European epidemiological data. BMJ 1998;317:371–5.
4. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991–1998. JAMA 1999;82:1519–22.
5. Ogden CL, Fryar CD, Carroll MD, Flegal KM. Mean body weight, height, and body mass index, United States 1960–2002. Adv Data 2004;347:1–17.
6. Gregg EW, Cadwell BL, Cheng YJ, et al. Trends in the prevalence and ratio of diagnosed to undiagnosed diabetes according to obesity levels in the U.S. Diabetes Care 2004;27:2806–12.
7. Botman SL, Moore TF, Moriarity CL, Parsons VL. Design and estimation for the National Health Interview Survey, 1995–2004. Vital Health Stat 2 2000;130:1–41.
8. Korn EL, Graubard BL. Analysis of health surveys. New York: Wiley, 1999.
9. Leibson CL, O'Brien PC, Atkinson E, Palumbo PJ, Melton LJ 3rd. Relative contributions of incidence and survival to increasing prevalence of adult-onset diabetes mellitus: a population-based study. Am J Epidemiol 1997;146:12–22.
10. Burke JP, Williams K, Gaskill SP, Hazuda HP, Haffner SM, Stern MP. Rapid rise in the incidence of type 2 diabetes from 1987 to 1996. Arch Intern Med 1999;159:1450–6.
11. Burke JP, O'Brien P, Ransom J, et al. Impact of case ascertainment on recent trends in diabetes incidence in Rochester, Minnesota. Am J Epidemiol 2002;155:859–65.
12. Millar WJ, Young TK. Tracking diabetes: prevalence, incidence and risk factors. Health Rep 2003;14:35–47.
13. Lipton RB, Liao Y, Cao G, Cooper RS, McGee D. Determinants of incident non-insulin-dependent diabetes mellitus among blacks and whites in a national sample. The NHANES I Epidemiologic Follow-up Study. Am J Epidemiol 1993, 138:826–39.
14. Gurwitz JH, Field TS, Glynn RJ, et al. Risk factors for non–insulin-dependent diabetes mellitus requiring treatment in the elderly. J Am Geriatr Soc 1994;42:1235–40.
15. Hara H, Egusa G, Yamakido M. Incidence of non-insulin-dependent diabetes mellitus and its risk factors in Japanese-Americans living in Hawaii and Los Angeles. Diabet Med 1996;13:S133–42.
16. Edelstein SL, Knowler WC, Bain RP, et al. Predictors of progression from impaired glucose tolerance to NIDDM: an analysis of six prospective studies. Diabetes 1997;46:701–10.
17. Hu FB, Manson JE, Stampfer MJ, et al. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. N Engl J Med 2001;345:790–7.
18. Lee ET, Welty TK, Cowan LD, et al. Incidence of diabetes in American Indians of three geographic areas: the Strong Heart Study. Diabetes Care 2003;25:49–54.
19. Weinstein AR, Sesso HD, Lee IM, et al. Relationship of physical activity vs body mass index with type 2 diabetes in women. JAMA 2004;292:1188–94.
20. Leibson CL, Williamson DF, Melton LJ 3rd, et al. Temporal trends in BMI among adults with diabetes. Diabetes Care 2001;24:1584–9.
21. Arias E. United States life tables, 2002. Natl Vital Stat Rep 2004;53:(6)1–40.
22. Gregg EW, Cheng YJ, Cadwell B, et al. Secular trends in cardiovascular disease risk factors according to body mass index in U.S. adults. JAMA 2005;293:1868–74.

23. Kochanek KD, Murphy SL, Anderson RN, Scott C. Deaths: Final data for 2002. Natl Vital Stat Rep 2004;53:(5)1–40.
24. Knowler WC, Pettiti DJ, Saad MF, Bennett PH. Diabetes mellitus in the Pima Indians: incidence, risk factors, and pathogenesis. Diabetes Metab Rev 1990;6:1–27.
25. Kriska AM, Saremi A, Hanson RL, et al. Physical activity, obesity, and the incidence of type 2 diabetes in a high-risk population. Am J Epidemiol 2003;158:669–75.
26. Brancati FL, Kao WH, Folsom AR, Watson RL, Szklo M. Incident type 2 diabetes mellitus in African American and white adults: the Atherosclerosis Risk in Communities Study. JAMA 2000;283:2253–9.
27. Resnick HE, Valsania P, Halter JB, Lin X. Differential effects of BMI on diabetes risk among black and white Americans. Diabetes Care 1998;21:1828–35.
28. Pan XR, Li GW, Hu YH, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Da Qing IGT and Diabetes Study. Diabetes Care 1997;20:537–44.
29. Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med 2001;344:1343–50.
30. Diabetes Prevention Program Research Group. The Diabetes Prevention Program: reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393–403.