REVIEW ARTICLE

Why Young Adults Hold the Key to Assessing the Obesity Epidemic in Children

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Despite significant increases in prevalence rates of childhood obesity in the United States during the past 2 decades, rates of type 2 diabetes mellitus among children at the population level have not followed a similar trajectory as those in adults. In this review, hypotheses for the contrasting findings in children compared with adults are explored, as are possible links between the trends in childhood obesity rates and increases in type 2 diabetes among young adults in the United States. This review concludes with observations about the profound policy implications from current patterns of type 2 diabetes among youth and particularly young adults and a proposed research agenda regarding childhood obesity and type 2 diabetes risk over the life course. *Arch Pediatr Adolesc Med. 2008;162(7):682-687*

Type 2 diabetes mellitus is a chronic disease associated with long-term microvascular complications, such as neuropathy, retinopathy, and end-stage renal disease, and macrovascular complications, including cardiovascular disease and stroke.[1,2] Because of its devastating complications and reported increases in prevalence,[3-7] type 2 diabetes has been described as one of the "major threats to human health" for the 21st century.[3]

TRENDS IN OBESITY AND TYPE 2 DIABETES PREVALENCE AMONG US ADULTS

Obesity is the hypothesized critical factor contributing to an increased risk for type 2 diabetes,[8-10] and rates of obesity in the United States have increased significantly. In adults, the prevalence of obesity (body mass index [BMI] [calculated as weight in kilograms divided by height in meters squared] ≥30) has increased more than 2-fold since the 1960s,[11,12] with 32.2% of adults classified as obese by 2004. Given the relation between obesity and diabetes, increases in type 2 diabetes among adults would be expected to parallel the increases in obesity and, in fact, that pattern is seen. **Figure 1** shows sharp increases in obesity prevalence among US adults between 1976 and 2000, and **Figure 2** shows increases in type 2 diabetes prevalence among US adults during the same period.[13]

TRENDS IN OBESITY AND TYPE 2 DIABETES PREVALENCE AMONG US CHILDREN

Rates of obesity among US children (BMI ≥95th percentile for age and sex) have increased even more dramatically, with a 3-fold increase since 1976 (**Figure 3**).[11,14,15] Presumably because of childhood obesity trends, reports surfaced in the mid-1990s regarding increasing numbers of children with type 2 diabetes. Initial studies from tertiary care clinics documented 10-fold increases in type 2 diabetes incidence between 1982 (0.7 per 100 000 population) and 1994 (7.2 per 100 000 population),[16] with type 2 diabetes accounting for 8% to 45% of new-onset diabetes cases.[17]

Further evidence of increases in childhood type 2 diabetes was based on studies in high-risk populations. The prevalence of type 2 diabetes doubled among Pima Indian adolescents between 1977-1986 and 1987-1996,[18] and type 2 diabetes incidence rates among Pima Indian children were 5.7 times higher in 1991-2003 compared with 1965-1977.[19] The Chicago Childhood Diabetes Registry also re-

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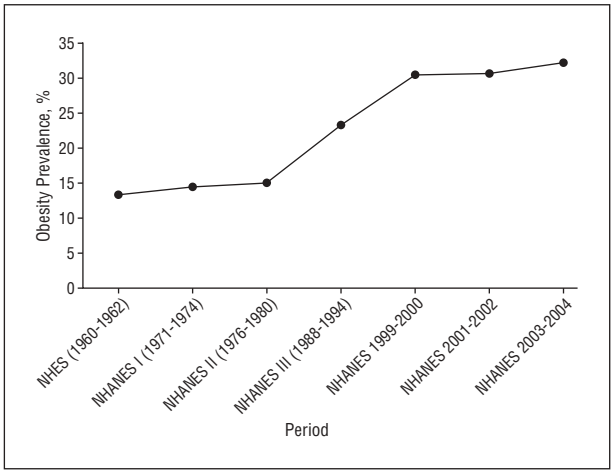

Figure 1. Trends in obesity prevalence among US adults. NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

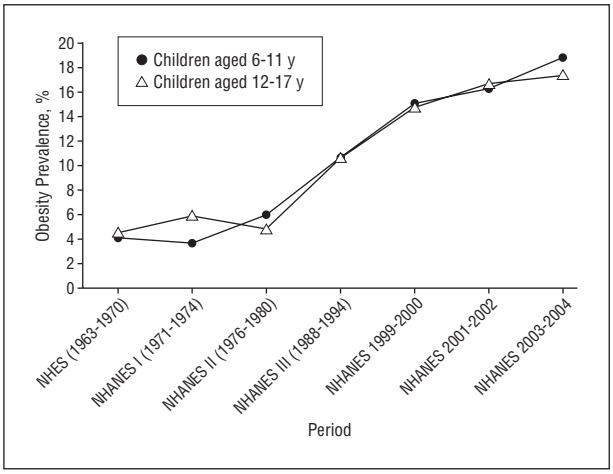

Figure 3. Trends in obesity prevalence among US children. NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

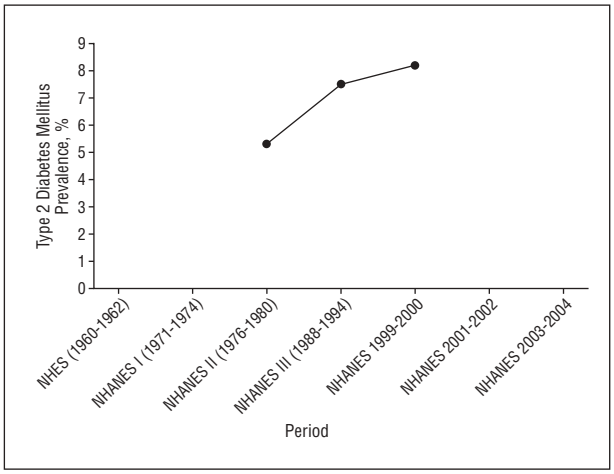

Figure 2. Trends in type 2 diabetes mellitus prevalence among US adults. NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

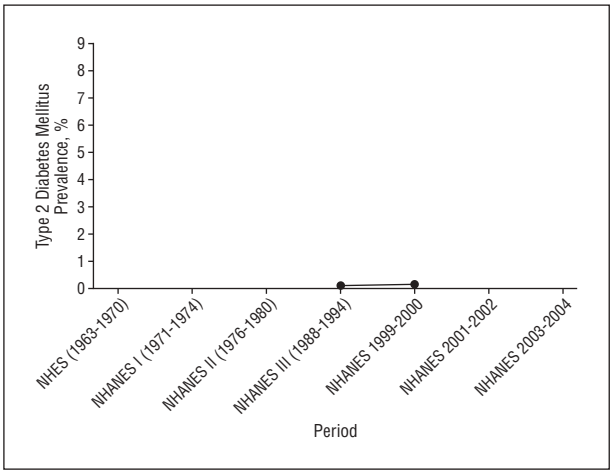

Figure 4. Trends in type 2 diabetes mellitus prevalence among US children aged 12 to 19 years. NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

ported increases in the proportion of children with type 2 diabetes among a subset of urban black and Latino children between 1985 and 2001.[20]

Prompted by these assessments of type 2 diabetes in high-risk groups, epidemiologic rates of childhood diabetes have been assessed more recently through larger population-based studies. **Figure 4** shows population-based rates of type 2 diabetes among adolescents aged 12 to 19 years between 1988 and 2000 based on National Health and Nutrition Examination Survey (NHANES) data.[21,22] Rates of type 2 diabetes among adolescents remained relatively stable, despite the notable increase in obesity prevalence among children seen during a similar period in Figure 3, in contrast to the pattern seen in adults (Figure 1 and Figure 2). Admittedly, the number of children with type 2 diabetes in these studies was low, with possible underestimation of type 2 diabetes prevalence because of treatment-based classification. However, these children were drawn from large representative population samples of 2867[21] and 4370 adolescents[22] that oversampled for racial/ethnic minorities.

The results of additional population-based studies in children appear to be consistent with NHANES data. The **Table** presents a comparison of diabetes prevalence estimates from population-based studies between 1988 and 2004.[21-25] Although slight differences in type 2 diabetes prevalence exist because of sampling variability and classification methods (treatment based[21,22] vs pathogenesis based[23,24]), similar rates were reported in a racially and socioeconomically diverse cohort of adolescents within an urban-suburban school district (0.12%).[23] Furthermore, the SEARCH for Diabetes in Youth Study,[24] a multicenter population-based study that used gold standard classification methods, reported an even lower type 2 diabetes prevalence among adolescents aged 10 to 19 years (0.04%) and children aged 0 to 19 years (0.02%).[24] Except for high-risk groups (ie, Pima Indians and urban minority children), no population-based data on type 2 diabetes prevalence are available before 1988, so significant increases in type 2 diabetes rates among the population of US adolescents before 1988 cannot be ruled out.

It may seem difficult to reconcile the documented increases in type 2 diabetes seen in population-based stud-

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Table. Population-Based Prevalence Rates of Diabetes Mellitus Among Children and Adolescents

	Adolescents				All Children	
	Fagot-Campagna et al[21]	Duncan[22]	Dolan et al[23]	Liese et al[24] (SEARCH)	Liese et al[24] (SEARCH)	Lee et al[25]
Study type	NHANES III	NHANES	School district in Cincinnati, Ohio	Multicenter study	Multicenter study	NSCH
Study years	1988-1994	1999-2002	2003	2001	2001	2003-2004
Total No. of children (No. with diabetes)	2867 (13)	4370 (18)	2501 (9)	Approximately 1.7 million (5030)	Approximately 3.5 million (6379)	102 353 (353)
Age range, y	12-19	12-19	9-20	10-19	0-19	0-17
Diabetes ascertainment	Self-report and fasting glucose level	Self-report	Self-report and 2-hour postload glucose level	Physician diagnosed	Physician diagnosed	Parent report
Diabetes classification	Treatment based	Treatment based	Pathogenesis based	Pathogenesis based	Pathogenesis based	No distinction for type 1 or type 2
Overall diabetes prevalence, % (95% confidence interval)	0.41 (0-0.86)	0.50 (0.24-0.76)	0.36[a]	0.28 (0.27-0.29)	0.18 (0.18-0.19)	0.32 (0.26-0.37)
Diabetes prevalence, %						
Type 1	0.29	0.35	0.24	0.23	0.15	NA
Type 2	0.12	0.15	0.12	0.04	0.02	NA
Type 2 diabetes among all diabetes, %	30	29	33	14	12	NA

Abbreviations: NA, not applicable; NHANES, National Health and Nutrition Examination Survey; NSCH, National Survey of Children's Health; SEARCH, SEARCH for Diabetes in Youth Study.

[a] Only the overall diabetes prevalence was given in Dolan et al.[23]

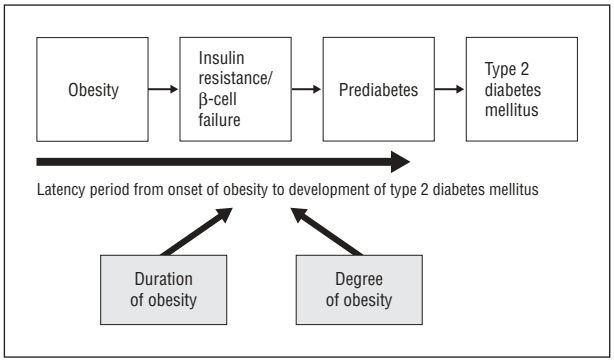

Figure 5. Hypothesized physiologic pathway leading to development of type 2 diabetes mellitus.

ies of high-risk groups with the lack of increases in type 2 diabetes measured in broader samples, but these findings are consistent with those of the SEARCH study, which found higher incidence rates of type 2 diabetes compared with type 1 diabetes mellitus among African American, Asian American, Hispanic, and American Indian adolescents, although among US children as a whole, the incidence of type 1 diabetes was still higher than the incidence of type 2 diabetes.[26] Therefore, increases in type 2 diabetes among high-risk minority groups may not yet be reflective of trends in the overall population. The lack of recent increases in type 2 diabetes rates among children compared with adults at the population level, despite significant increases in obesity, demonstrates that the overall burden of type 2 diabetes is still concentrated mostly among adults.

LATENCY PERIOD BETWEEN OBESITY AND TYPE 2 DIABETES

The absence of concurrent increases in childhood obesity and type 2 diabetes at the population level may be largely attributable to a latency period between obesity and type 2 diabetes. **Figure 5** shows the hypothesized physiologic pathway leading to development of type 2 diabetes.[27-29] Obesity is a risk factor for development of insulin resistance, with pancreatic β cells compensating for insulin resistance by augmenting insulin secretion. The failure of the β cells to maintain adequate insulin secretion is believed to cause prediabetes, eventually leading to type 2 diabetes. Consistent with this model, studies in Pima Indians have shown that the latency period between onset of obesity and type 2 diabetes can last 10 years or longer.[30] Because of this latency period, childhood obesity trends likely have a delayed effect on rates of type 2 diabetes, reflected in significant increases in type 2 diabetes among young adults who were obese as children.

INFLUENCE OF DEGREE AND DURATION OF OBESITY ON THE LATENCY PERIOD

Both degree and duration of obesity likely influence the length of the latency period. A number of studies[10,31] have shown that the higher the BMI, the higher the risk of incident type 2 diabetes, with a recent study[32] finding an inverse linear relation between age of diagnosis of type 2 diabetes and BMI. For example, mean BMI at diagnosis was 38.3 for individuals younger than 30 years, 35.9

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for individuals 46 to 50 years old, and 31.1 for individuals 66 to 70 years old, suggesting that degree of obesity will influence the timing of incident type 2 diabetes. Studies[30,33] have also shown that a longer duration of obesity is associated with a higher type 2 diabetes incidence after controlling for age, sex, and current BMI. The degree and duration of obesity extending from childhood through young adulthood may confer a cumulative risk of type 2 diabetes analogous to the relation between pack-years of smoking and lung cancer[33]; this risk is accumulating at an unprecedented rate given recent childhood obesity trends.

CHILDHOOD OBESITY TRENDS

In addition to absolute increases in obesity prevalence, the degree of obesity among US children has increased, resulting in shifts in the overall weight distribution.[15,34] Jolliffe[34] calculated the extent of obesity for US children, defined as the average amount by which each child's BMI exceeded his or her age- and sex-specific obesity threshold. Although the prevalence of obesity increased by 182% between 1971 and 2000, the extent of obesity increased by 247% during the same period.[34] Children are also increasingly becoming obese at younger ages (6 months to 5 years).[14] Because more US children are becoming heavier at earlier ages, younger cohorts may experience a greater degree and longer duration of obesity during their lifetime, which could lead to a shortening of the latency period and onset of type 2 diabetes in young adulthood.

TRENDS IN HOSPITALIZATIONS ASSOCIATED WITH DIABETES

Consistent with this hypothesis, recent studies[6,35] suggest possible increases in rates of diabetes among US young adults. We recently assessed trends in hospitalizations associated with a diagnosis of diabetes for individuals from birth to the age of 29 years, using a nationally representative sample of hospital discharges between 1993 and 2004. During the 12-year period, we found significant increases among young adults aged 20 to 29 years (185.2 per 100 000 population in 1993 to 275.0 per 100 000 population in 2004, representing a 48% increase) but not among children 19 years or younger.[35]

This study could not distinguish between diabetes type. Furthermore, individuals with diabetes may not require inpatient hospitalization. However, type 2 diabetes accounts for 90% to 95% of adult diabetes,[7] and according to the Centers for Disease Control and Prevention (CDC),[36] hospitalizations among individuals with diabetes have decreased since 1980. Therefore, increases in population-adjusted hospitalization rates for young adults are likely an indication of increasing type 2 diabetes prevalence in the young adult population.[36] Increases in particular were seen after 2000 among a generation of young adults who grew up in the midst of the childhood obesity epidemic during the late 1970s and early 1980s. The birth cohort effects of large increases in childhood obesity may be presenting just now as the first indication of significant increases in type 2 diabetes among young adults.

CONSEQUENCES OF EARLY-ONSET TYPE 2 DIABETES

An epidemiologic shift to younger ages at onset of type 2 diabetes may have profound intergenerational consequences. The onset of type 2 diabetes among young women during the child-bearing years may lead to a possible "vicious cycle" of type 2 diabetes in subsequent generations because studies have shown a higher risk of obesity and type 2 diabetes among offspring with intrauterine exposure to maternal diabetes.[37]

Furthermore, studies suggest that early-onset type 2 diabetes may represent a more aggressive disease with regard to cardiovascular outcomes, rates of end-stage complications, and overall mortality. One recent study[38] described the rates of diabetes complications for individuals with early-onset (aged 18-44 years) compared with late-onset (aged ≥45 years) type 2 diabetes after initial diagnosis. Early-onset type 2 diabetes was associated with a 14-fold higher hazard of developing a myocardial infarction compared with age- and sex-adjusted controls without diabetes, a far stronger association than found in the late-onset type 2 diabetes group, who had a 4-fold higher hazard for late-onset type 2 diabetes compared with controls.[38]

Because end-stage complications develop as a function of duration of disease,[39] young adults with type 2 diabetes will likely face greater morbidity and mortality during their lifetime compared with individuals whose diabetes is diagnosed at older ages. One Pima Indian study[40] documented higher incidence rates of end-stage renal disease and mortality among individuals with youth-onset type 2 diabetes compared with adult-onset type 2 diabetes, with a longer duration of diabetes largely accounting for these differences.

Finally, a number of studies[41,42] have shown that the relative risk of death attributable to type 2 diabetes in adults is highest in the youngest age groups and declines with increasing age. Accordingly, demographers are predicting that recent childhood obesity trends will result in a shorter life expectancy for future generations as a result of diseases including type 2 diabetes.[43]

A LIFE COURSE APPROACH TO CHILDHOOD OBESITY

A life course approach to chronic disease risk suggests that risk factors and experiences early in life impact long-term health and disease outcomes,[44,45] and interventions to attenuate early risk factors in childhood may lead to prevention of disease in adulthood.[46] The childhood obesity epidemic has important implications for type 2 diabetes risk during the life course because of possible increases in type 2 diabetes during young adulthood. If cumulative exposure to obesity in childhood is associated with early onset of type 2 diabetes, then health care investments or policy interventions to prevent or treat childhood obesity to reduce this exposure will have important effects on the overall health of the population, although improved health and related health economic outcomes may not be noted for several years.

Given the possible link between trends in childhood obesity and trends in type 2 diabetes among young adults, health

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care policy and financing may need to shift focus to disease prevention interventions earlier in the life course.

First, investment in and incentives for screening and treatment of childhood obesity in the clinical setting are likely needed, as studies have shown greater reversibility of obesity at younger ages.[47] Unfortunately, obesity prevention and treatment-related services for children are not usually covered by third-party payers.[48] In contrast, programs for managing adult chronic diseases (type 2 diabetes, hypertension, and cardiovascular disease) have increased in number and scope.[49,50] This imbalance is reflected in overall health care spending for the population, which is substantially lower in US children compared with US adults on a per capita basis, with proportional decreases in spending during the past decade for children accompanied by proportional increases in spending among adults.[51]

Second, schools represent a critical arena for obesity prevention among children.[52] School-based interventions that promote decreased television and video viewing time,[53] increased physical activity and healthy eating,[54] and elimination of sugar-sweetened beverage intake[55] have been shown to be effective in lowering BMI and decreasing the prevalence of obesity, suggesting the need for increased funding for conducting and monitoring the effects of school-based obesity prevention initiatives.

Third, although controversial, the importance of monitoring population trends in obesity by school-based BMI measurement[56,57] is critical for assessing the effectiveness of innovative school-based policy interventions.[58,59] For example, Arkansas passed legislation in 2003 that included a variety of measures to combat childhood obesity. Through school-based BMI assessment, they were able to document that multimodal interventions have apparently halted the progression of childhood obesity within 2 years of implementation.[57]

FUTURE RESEARCH AGENDA FOR CHILDHOOD OBESITY AND TYPE 2 DIABETES

The CDC estimates that approximately 48.3 million individuals in the United States will have diagnosed diabetes by 2050.[60] Because childhood obesity trends have not been accounted for, their projections may substantially underestimate future cases of type 2 diabetes. Therefore, further studies are needed to model the impact of the dynamics of childhood obesity on future rates and age at onset of type 2 diabetes and to assess both the effectiveness and cost-effectiveness of interventions for preventing type 2 diabetes over the life course.

Modeling the link between childhood obesity and type 2 diabetes risk over the life course will be critical for estimating the changing rates of microvascular and macrovascular complications and changes in life expectancy owing to trends in childhood obesity. Information from the model will be highly relevant for understanding the impact of potential increases in incident type 2 diabetes in the clinical setting, in terms of access to and provision of services for those affected, and the potential future financial burden on Medicare, the primary payer for end-stage renal disease. It will also be essential for assessing the effectiveness of interventions across the life course for preventing type 2 diabetes and its complications. Using a lifetime simulation, Herman et al[61] showed that both lifestyle modification and metformin were cost-effective interventions for delaying or preventing the onset of type 2 diabetes among high-risk adults, concluding that diabetes prevention interventions among high-risk adults represent a worthwhile investment for policy makers. Information regarding the cost-effectiveness of obesity prevention and treatment interventions earlier in the life course is needed for comparison, which will guide future health policy to evaluate which high-risk demographic groups should be targeted for interventions and to determine at what ages across the life course interventions should be introduced to achieve maximal benefit.

One recent study[19] in the Pima Indians showed that between 1965 and 2003 the greatest increases in type 2 diabetes incidence occurred among children aged 5 to 14 years and, in fact, decreases in type 2 diabetes incidence occurred among individuals aged 25 to 34 years. This epidemiologic shift to an even earlier onset of type 2 diabetes, reaching into childhood and adolescence, may be a scenario faced by the entire US population if the childhood obesity epidemic continues unabated. Given that the current US health care system is not designed to promote disease prevention over the life course, the traditional models of "pediatric" and "adult" health care will need to be challenged, leading to development of new models of care that address long-term chronic disease risk originating in childhood and extending into adulthood. There are several diseases to which such a new life-course model could be applied, but perhaps no condition more prevalent among children than obesity and no consequence more clinically severe than type 2 diabetes for which a life-course model will be a crucial platform for success.

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REFERENCES

1. Klein R. Hyperglycemia and microvascular and macrovascular disease in diabetes. *Diabetes Care*. 1995;18(2):258-268.
2. Orchard TJ, Dorman JS, Maser RE, et al. Prevalence of complications in IDDM by sex and duration: Pittsburgh Epidemiology of Diabetes Complications Study II. *Diabetes*. 1990;39(9):1116-1124.
3. Zimmet P, Alberti KG, Shaw J. Global and societal implications of the diabetes epidemic. *Nature*. 2001;414(6865):782-787.
4. Mokdad AH, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The con-

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tinuing epidemics of obesity and diabetes in the United States. *JAMA*. 2001; 286(10):1195-1200.
5. Mokdad AH, Ford ES, Bowman BA, et al. The continuing increase of diabetes in the US [letter]. *Diabetes Care*. 2001;24(2):412.
6. Mokdad AH, Ford ES, Bowman BA, et al. Diabetes trends in the U.S.: 1990-1998. *Diabetes Care*. 2000;23(9):1278-1283.
7. Engelgau MM, Geiss LS, Saaddine JB, et al. The evolving diabetes burden in the United States. *Ann Intern Med*. 2004;140(11):945-950.
8. Goran MI, Ball GD, Cruz ML. Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents. *J Clin Endocrinol Metab*. 2003;88 (4):1417-1427.
9. Hannon TS, Rao G, Arslanian SA. Childhood obesity and type 2 diabetes mellitus. *Pediatrics*. 2005;116(2):473-480.
10. Knowler WC, Pettitt DJ, Saad MF, et al. Obesity in the Pima Indians: its magnitude and relationship with diabetes. *Am J Clin Nutr*. 1991;53(6)(suppl):1543S-1551S.
11. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA*. 2006; 295(13):1549-1555.
12. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999-2000. *JAMA*. 2002;288(14):1723-1727.
13. 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 US. *Diabetes Care*. 2004;27(12):2806-2812.
14. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. *JAMA*. 2002;288(14): 1728-1732.
15. Troiano RP, Flegal KM. Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics*. 1998;101(3, pt 2):497-504.
16. Pinhas-Hamiel O, Dolan LM, Daniels SR, Standiford D, Khoury PR, Zeitler P. Increased incidence of non-insulin-dependent diabetes mellitus among adolescents. *J Pediatr*. 1996;128(5, pt 1):608-615.
17. Fagot-Campagna A, Pettitt DJ, Engelgau MM, et al. Type 2 diabetes among North American children and adolescents: an epidemiologic review and a public health perspective. *J Pediatr*. 2000;136(5):664-672.
18. Dabelea D, Hanson RL, Bennett PH, Roumain J, Knowler WC, Pettitt DJ. Increasing prevalence of type II diabetes in American Indian children. *Diabetologia*. 1998; 41(8):904-910.
19. Pavkov ME, Hanson RL, Knowler WC, Bennett PH, Krakoff J, Nelson RG. Changing patterns of type 2 diabetes incidence among Pima Indians. *Diabetes Care*. 2007;30(7):1758-1763.
20. Lipton RB, Drum M, Burnet D, et al. Obesity at the onset of diabetes in an ethnically diverse population of children: what does it mean for epidemiologists and clinicians? *Pediatrics*. 2005;115(5):e553-e560. doi:10.1542/peds.2004-1448.
21. Fagot-Campagna A, Saaddine JB, Flegal KM, Beckles GL. Diabetes, impaired fasting glucose, and elevated HbA1c in U.S. adolescents: the Third National Health and Nutrition Examination Survey. *Diabetes Care*. 2001;24(5):834-837.
22. Duncan GE. Prevalence of diabetes and impaired fasting glucose levels among US adolescents: National Health and Nutrition Examination Survey, 1999-2002. *Arch Pediatr Adolesc Med*. 2006;160(5):523-528.
23. Dolan LM, Bean J, D'Alessio D, et al. Frequency of abnormal carbohydrate metabolism and diabetes in a population-based screening of adolescents. *J Pediatr*. 2005;146(6):751-758.
24. Liese AD, D'Agostino RB Jr, Hamman RF, et al. The burden of diabetes mellitus among US youth: prevalence estimates from the SEARCH for Diabetes in Youth Study. *Pediatrics*. 2006;118(4):1510-1518.
25. Lee JM, Herman WH, McPheeters ML, Gurney JG. An epidemiologic profile of children with diabetes in the U.S. *Diabetes Care*. 2006;29(2):420-421.
26. Dabelea D, Bell RA, D'Agostino RB Jr, et al. Incidence of diabetes in youth in the United States. *JAMA*. 2007;297(24):2716-2724.
27. Gungor N, Hannon T, Libman I, Bacha F, Arslanian S. Type 2 diabetes mellitus in youth: the complete picture to date. *Pediatr Clin North Am*. 2005;52(6):1579-1609.
28. Cruz ML, Shaibi GQ, Weigensberg MJ, Spruijt-Metz D, Ball GD, Goran MI. Pediatric obesity and insulin resistance: chronic disease risk and implications for treatment and prevention beyond body weight modification. *Annu Rev Nutr*. 2005; 25:435-468.
29. Inzucchi SE, Sherwin RS. The prevention of type 2 diabetes mellitus. *Endocrinol Metab Clin North Am*. 2005;34(1):199-219, viii.
30. Everhart JE. Duration of obesity increases the incidence of NIDDM. *Diabetes*. 1992; 41(2):235-240.
31. 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*. 2006;113(25):2914-2918.
32. Hillier TA, Pedula KL. Characteristics of an adult population with newly diagnosed type 2 diabetes: the relation of obesity and age of onset. *Diabetes Care*. 2001;24(9):1522-1527.
33. Brancati FL, Wang NY, Mead LA, Liang KY, Klag MJ. Body weight patterns from 20 to 49 years of age and subsequent risk for diabetes mellitus: the Johns Hopkins Precursors Study. *Arch Intern Med*. 1999;159(9):957-963.
34. Jolliffe D. Extent of overweight among US children and adolescents from 1971 to 2000. *Int J Obes Relat Metab Disord*. 2004;28(1):4-9.
35. Lee JM, Okumura MJ, Freed GL, Menon RK, Davis MM. Trends in hospitalizations for diabetes among children and young adults: United States, 1993-2004. *Diabetes Care*. 2007;30(12):3035-3039.
36. Centers for Disease Control and Prevention. Diabetes Data and Trends. http://www.cdc.gov/diabetes/statistics/dmany/fig7.htm. Accessed August 2, 2007.
37. Dabelea D, Hanson RL, Lindsay RS, et al. Intrauterine exposure to diabetes conveys risks for type 2 diabetes and obesity: a study of discordant sibships. *Diabetes*. 2000;49(12):2208-2211.
38. Hillier TA, Pedula KL. Complications in young adults with early-onset type 2 diabetes: losing the relative protection of youth. *Diabetes Care*. 2003;26(11):2999-3005.
39. Nathan DM. Long-term complications of diabetes mellitus. *N Engl J Med*. 1993; 328(23):1676-1685.
40. Pavkov ME, Bennett PH, Knowler WC, Krakoff J, Sievers ML, Nelson RG. Effect of youth-onset type 2 diabetes mellitus on incidence of end-stage renal disease and mortality in young and middle-aged Pima Indians. *JAMA*. 2006;296(4): 421-426.
41. Tierney EF, Geiss LS, Engelgau MM, et al. Population-based estimates of mortality associated with diabetes: use of a death certificate check box in North Dakota. *Am J Public Health*. 2001;91(1):84-92.
42. Saydah SH, Eberhardt MS, Loria CM, Brancati FL. Age and the burden of death attributable to diabetes in the United States. *Am J Epidemiol*. 2002;156(8): 714-719.
43. Olshansky SJ, Passaro DJ, Hershow RC, et al. A potential decline in life expectancy in the United States in the 21st century. *N Engl J Med*. 2005;352(11): 1138-1145.
44. Kuh D, Ben-Shlomo Y. *A Life Course Approach to Chronic Disease Epidemiology*. Oxford, England: Oxford University Press; 2004.
45. Forrest CB, Riley AW. Childhood origins of adult health: a basis for life-course health policy. *Health Aff (Millwood)*. 2004;23(5):155-164.
46. Halfon N, Hochstein M. Life course health development: an integrated framework for developing health, policy, and research. *Milbank Q*. 2002;80(3):433-479.
47. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr*. 2002;76(3):653-658.
48. Schwimmer JB. Childhood obesity: the case for coverage. *Harv Health Policy Rev*. 2003;4(2):62-72.
49. Wagner EH, Austin BT, Korff MV. Organizing care for patients with chronic illness. *Milbank Q*. 1996;74(4):511-544.
50. Wagner EH, Davis C, Schaefer J, Von Korff M, Austin B. A survey of leading chronic disease management programs: are they consistent with the literature? *Manag Care Q*. 1999;7(3):56-66.
51. Freed GL, Fant K. The impact of the "aging of America" on children. *Health Aff (Millwood)*. 2004;23(2):168-174.
52. Story M, Kaphingst KM, French S. The role of schools in obesity prevention. *Future Child*. 2006;16(1):109-142.
53. Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA*. 1999;282(16):1561-1567.
54. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med*. 1999;153(4):409-418.
55. James J, Thomas P, Cavan D, Kerr D. Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial. *BMJ*. 2004; 328(7450):1237.
56. Kantor J. As obesity fight hits cafeteria, many fear a note from school. *New York Times*. January 8, 2007. http://www.nytimes.com/2007/01/08/health/08obesity.html?_r=1&oref=slogin. Accessed February 15, 2007.
57. Ryan KW, Card-Higginson P, McCarthy SG, Justus MB, Thompson JW. Arkansas fights fat: translating research into policy to combat childhood and adolescent obesity. *Health Aff (Millwood)*. 2006;25(4):992-1004.
58. Sallis JF, McKenzie TL, Conway TL, et al. Environmental interventions for eating and physical activity: a randomized controlled trial in middle schools. *Am J Prev Med*. 2003;24(3):209-217.
59. French SA, Stables G. Environmental interventions to promote vegetable and fruit consumption among youth in school settings. *Prev Med*. 2003;37(6, pt 1): 593-610.
60. Narayan KMV, Boyle JP, Geiss LS, Saaddine JB, Thompson TJ. Impact of recent increase in incidence on future diabetes burden. *Diabetes Care*. 2006;29(9): 2114-2116.
61. Herman WH, Hoerger TJ, Brandle M, et al. The cost-effectiveness of lifestyle modification or metformin in preventing type 2 diabetes in adults with impaired glucose tolerance. *Ann Intern Med*. 2005;142(5):323-332.

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