Type 2 diabetes among North American children and adolescents: An epidemiologic review and a public health perspective

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Objectives: To review the magnitude, characteristics, and public health importance of type 2 diabetes in North American youth.

Results: Among 15- to 19-year-old North American Indians, prevalence of type 2 diabetes per 1000 was 50.9 for Pima Indians, 4.5 for all US American Indians, and 2.3 for Canadian Cree and Ojibway Indians in Manitoba. From 1967-1976 to 1987-1996, prevalence increased 6-fold for Pima Indian adolescents. Among African Americans and whites aged 10 to 19 years in Ohio, type 2 diabetes accounted for 33% of all cases of diabetes. Youth with type 2 diabetes were generally 10 to 19 years old, were obese and had a family history of type 2 diabetes, had acanthosis nigricans, belonged to minority populations, and were more likely to be girls than boys. At follow-up, glucose control was often poor, and diabetic complications could occur early.

Conclusions: Type 2 diabetes is an important problem among American Indian and First Nation youth. Other populations have not been well studied, but cases are now occurring in all population groups, especially in ethnic minorities. Type 2 diabetes among youth is an emerging public health problem, for which there is a great potential to improve primary and secondary prevention. (J Pediatr 2000;136:664-72)

When diabetes mellitus strikes children and adolescents, it is routinely assumed to be type 1, the autoimmune form of the disease that leads to a permanent deficiency in insulin secretion.[1] Conversely, type 2 diabetes, which is characterized primarily by insulin resistance and a relative decrease in insulin secretion, has typically been considered a disease of adults. However, during the last 2 decades, pediatric type 2 diabetes has been reported in US Pima Indians[2] and Canadian First Nation People.[3-10] Recently, numerous case reports have appeared describing type 2 diabetes in American Indian youth,[11-13] as well as their African American, Hispanic, and white peers.[14-21] Among adults, type 2 diabetes may remain asymptomatic and undiagnosed for years, and its major risk factors include obesity, a sedentary lifestyle, and a family history of the disease. Nevertheless, similarities exist between type 1 and 2 diabetes, including the potential for an acute onset (ie, ketosis and acidosis) and obligatory insulin treatment. These factors can lead to the misclassification of type 2 diabetes as type 1 among youth.

In light of recent interest in type 2 diabetes among North American children and adolescents, we conducted an epidemiologic review in which we describe current knowledge about the magnitude and characteristics of the disease. Because type 2 diabetes is considered a general public health problem,[22] we discuss the public health importance of the disease among North American youth.

Methods

We searched the MEDLINE database for articles on type 2 diabetes in youth published between January 1966

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Table I. Selected current estimates of the magnitude of type 2 diabetes in North American children and adolescents, in population- and clinic-based studies and case series

Study and reference*	Years	Race/ethnicity	Age (y)	Sample size	No. of cases	Estimates
Population-based studies						Prevalence per 1000 and 95% CI
New Mexico[23]	1991-1992	Navajo Indians	12-19	142	2†	14.1 *[0–33.5]*†
Arizona[11,a]	1992-1996	Pima Indians	10-14	672	15	22.3 *[11.1–33.5]*
			15-19	530	27	50.9 *[32.2-69.6]*
Manitoba[7]	1996-1997	Cree and Ojibway Indians	4-19	717	8	11.1 *[3.4-18.8]*
			10-19	U	7	0 for boys and 36.0 for girls
NHANES III[b]	1988-1994	Whites, and African and Mexican Americans, all US	12-19	2,867	13†	4.1 [0-8.6] †
Clinic-based studies						
Indian Health Services[13]	1996	American Indians, all US	0-14	402,580	518†	1.3†
			15-19	111,239	498†	4.5†
Manitoba[c]	1998	Cree and Ojibway Indians	5-14	20,900	20	1.0
			15-19	8,400	19	2.3
Clinic-based study						Incidence per 100,000/y
Cincinnati, OH[14]	1994	Whites and African Americans	0-19	U	U	3.5
			10-19	U	U	7.2
Case series				‡		Percent of type 2 diabetes among new cases of diabetes
Cincinnati, OH[14]	1982-1994	Whites and African Americans	0-19	1,027§	54§	16§ (in 1994)
			10-19	U	U	33§ (in 1994)
Charleston, SC[16]	1997	African Americans	10-19	97	45	46
Little Rock, AR[17]	1988-1995	Whites, Hispanics, and African Americans	0-19	U	50	U
San Diego, CA[19]	1993-1994	Whites, Hispanics, and African and Asian Americans	0-16	160§	13§	8§
San Antonio, TX[20]	1990-1997	Whites, Hispanics	U	560§	101§	18§
Ventura, CA[21]	1990-1994	Hispanics	0-17	31§	14§	45§

Numbers in italics are estimates.
NHANES III, National Health and Nutrition Examination Survey III; *U*, unknown data.
*Numbered references may be found in reference list; references a, b, and c are personal communications: a, D. Dabelea; b, A. Fagot-Campagna; c, H. Dean.
†Estimates include cases of type 1 diabetes.
‡In case series, the sample size refers to the total number of cases of diabetes (types 1 and 2).
§Incident cases.

and June 1999, using the following key words: non-insulin-dependent diabetes mellitus; preschool child, child, or adolescence; North America, North American Indians, Eskimos, Asian Americans, Blacks, or Hispanic Americans. A total of 182 publications were identified; 26 contained relevant epidemiologic data. Six additional reports were identified from abstracts or conference summaries. Four unpublished analyses of large population-based studies or hospital data were obtained from personal communications.

Epidemiology of Type 2 Diabetes Among North American Children and Adolescents

SIZE OF THE PROBLEM (TABLE I). We collated data on prevalence (the number of persons having the disease divided by the population size) and inci-

Table II. Characteristics of 578 North American children and adolescents at diagnosis of type 2 diabetes

Characteristics	Study reference* and sample size				
	Cincinnati, OH[14] (n = 54)	Charleston, SC[15] (n =39)	Little Rock, AR[17] (n = 50)	San Diego, CA[19] (n = 18)	San Antonio, TX[20] (n = 101)
Ethnicity (%)					
African American	69	100	74	11	U
Hispanic			2	67	83
White	31		24	17	U
American Indian				‡	
Female/male ratio	1.7	1.3	1.6	2.0	*3.0*
Family history (%)					
First- or second-degree relative	85	*95*	U	*87*	*74*
First-degree relative	65	72	U	*80*	*45*
Mean age (y)	14	13	14	13	*13*
Youngest age (y)	*8*	*7*	8	5	*6*
Mean BMI (kg/m^2)	38	30	35	27	U
Acanthosis nigricans (%)	60	56	86	67	92
Presence of weight loss (%)	*19-100*	*31*§	40	U	*50*
Mean HbA1C (%)	U	12	11	U	U
Ketosis (%)	U	79§	16-18	33	U
Ketoacidosis (%)	U	46§	>25	*14*	U
Diagnosis based on (%)					
Symptoms	*66*	U	U	U	U
Screening	*3*‖	U	U	U	U
Urinalysis	*32*	U	U	U	U

Numbers in italics were either inferred from the original publication, estimated from a smaller total number of cases because of missing information, or obtained from a personal communication.
U, Unknown data.
*Numbered references may be found in reference list. Numbers of cases may differ from those reported in Table I because of missing data for some cases or inclusion of additional cases from satellite clinics.
†This case series included youth diagnosed by systematic screening between 1965 and 1998.
‡One Cambodian case.
§History of weight loss, ketosis, or ketoacidosis.
‖Evaluation for obesity or strong family history of diabetes.

dence rate (the number of new cases divided by the population size per year). Data sources included population-based studies in the United States and Canada, health services administrative data for American Indians in the United States and First Nation People in Canada, two US registries of type 1 diabetes, and US hospital and clinic case reports.

POPULATION-BASED STUDIES. Most population-based studies estimated the prevalence based on a single 2-hour post-load glucose concentration ≥11.1 mmol/L (200 mg/dL) or a history of type 2 diabetes confirmed by medical chart review. In the 1991-1992 Navajo Health and Nutrition Survey, the prevalence of diabetes (type unknown) among 142 American Indians aged 12 to 19 years was 14.1 per 1000, and one of the two identified cases was diagnosed at screening.[23] In Arizona, 125 of 5274 Pima Indians aged 0 to 19 years developed type 2 diabetes over a 30-year period (1967-1996).[11] In the years 1992 to 1996, the prevalence was 22.3 per 1000 for 10- to 14-year-olds and 50.9 per 1000 for 15- to 19-year-olds. From 1967-1976 to 1987-1996, prevalence increased approximately 4- to 6-fold for both age groups.

Three Canadian diabetes screening surveys were available from the Cree and Ojibway First Nation People. In 1989, no diabetes cases were found among 106 adolescents aged 15 to 19 years in Quebec.[24] The Sandy Lake Health and Diabetes Project, a 1993-1995 survey in Ontario, also found no type 2 diabetes among boys aged 10 to

Study reference* and sample size				
Ventura, CA[21] (n = 21)	Chicago, IL[28] (n = 160)	Sioux Lookout Zone, Ontario[9] (n = 15)	Manitoba[5] (n = 20)	Gila River, AZ[12†] (n = 100)
	75			
100	25			
		100	100	100
0.8	1.7	14	4.0	1.7
100	U	*93*	*100*	U
>60	50	*69*	*100*	U
14	14	12	12	16
10	U	7	7	4
33	33	*29*	*26*	35
U	U	U	U	U
U	*62*	*30*	0	U
10	U	*13*	13	6
33	U	*50*	25	U
5	52	U	U	U
86	U	100	25	U
14‖	U	0	U	100
	U	0	75	U

19 years, but among girls the prevalence was 40 per 1000.[10] A 1996-1997 survey conducted in Manitoba among 717 school youth demonstrated a prevalence of 11.1 per 1000 for the 4- to 19-year-olds and 36 per 1000 for girls aged 10 to 19 years.[7] Of the 8 identified cases, 2 had been previously diagnosed; the remainder were identified by a fasting blood glucose level ≥7 mmol/L (126 mg/dL).

Three recent population-based studies estimated the prevalence of diabetes in other youth groups. In 1992 and 1993, based on fasting glucose, the Corpus Christi Child Heart Study identified no cases of diabetes among 403 Hispanic and white children aged 8 to 9 years from 8 elementary schools.[25] In 1992 and 1993, among 3128 youth aged 5 to 17 years, the Bogalusa Study identified 6 children taking insulin for diabetes and another 2 who had fasting glucose values between 7 and 7.8 mmol/L (126 and 140 mg/dL) (Freedman DS. Unpublished data). This is equivalent to a diabetes prevalence (type unknown) of 2.6 per 1000.

In the 1988-1994 National Health and Nutrition Examination Survey, a representative sample of the American population, 2867 youth aged 12 to 19 years, had glucose levels measured (Fagot-Campagna A. Unpublished data). Eleven adolescents were being treated for diabetes: 9 reported taking insulin, and 2 were using other medications. Two other adolescents were receiving no treatment but had high fasting (≥7 mmol/L or 126 mg/dL) or random (≥11.1 mmol/L or 200 mg/dL) glucose levels. Thus the estimated diabetes prevalence (type unknown) was about 4.1 per 1000 for US adolescents aged 12 to 19 years.

REGISTRIES AND CASE SERIES AMONG AMERICAN INDIAN AND FIRST NATION CHILDREN AND ADOLESCENTS. To estimate the prevalence of diagnosed diabetes, researchers used the Indian Health Service administrative data, which include data on approximately 60% of American Indians and Alaska Natives. Analyses for all areas served by Indian Health Service, with the exception of 46 service units with incomplete data, provided a prevalence estimate of 1.3 per 1000 during the years 1988 to 1996 for those aged 0 to 14 years.[13] Among those aged 15 to 19 years, prevalence increased 54%, from 2.9 to 4.5 per 1000 ($P < .001$) between 1988 and 1996.

In Ontario and Manitoba between 1983 and 1990, the Canadian Health Services reported prevalence estimates of diagnosed diabetes (type unknown) ranging between 0.5 and 1.7 per 1000 for Cree and Ojibway Indians aged 0 to 14 years.[3-5,8] Recent analyses from Ontario,[9] Manitoba,[6] and Saskatchewan (Dean H, presentation at CDC workshop, Oct 1998) provide estimates ranging from 1.0 to 2.5 per 1000 for the age group 5 to 14 years and from 2.3 to 3.5 for the age group 15 to 19 years. No diabetes cases were reported among youth less than 15 years old who were members of other First Nation tribes in Canada.[6]

US REGISTRIES OF TYPE 1 DIABETES AMONG CHILDREN AND ADOLESCENTS. Diabetes registries in the United States record new cases of type 1 diabetes defined by age at onset and treatment with insulin. Because type 2 diabetes may present in a manner similar to that of type 1 diabetes, the registries of type 1 diabetes may provide clues about the incidence of type 2 diabetes. In the Allegheny County registry in Pennsylvania, the 1990-1994 incidence rate among those aged 15 to 19 years was almost 3 times higher among African Americans than among whites (30.4 vs 11.2/100,000/y, $P = .001$).[26] Among African Americans, the 1990-1994 incidence was more than 3 times higher than the 1980-1984 incidence (7.6/100,000/yr). These large differences between African Americans and whites suggest that type 2 diabetes cases may have been misclassified as type 1 cases in the registry.

Between 1985 and 1994 among boys and girls aged 0 to 17 years, the Chicago registry in Illinois reported a stable diabetes incidence for African Americans (13.0 and 16.1/100,000/y) and for Hispanics (10.5 and 10.6/100,000/y).[27,28] However, the annual rates were unusually higher for African Americans than Hispanics aged 10 to 14 years (24.1 and 16.2/100,000) and 15 to 17 years (20.5 and 12.2/100,000). A review of medical records for 645 youths with diabetes identified 190 patients aged 0 to 17 years who, based on discontinuation of insulin treatment, were judged not to have type 1 diabetes. In this group the proportion of cases that were not type 1 was estimated to be 17% and 27% for African American boys and girls and 16% and 19% for Hispanic boys and girls, respectively.

US CASE SERIES AMONG WHITE, AFRICAN AMERICAN, AND HISPANIC CHILDREN AND ADOLESCENTS. Six pediatric hospitals or clinics have published reports on type 2 diabetes, and 5 of them reported the percentage of all diabetes cases that were type 2. In a report from Cincinnati, Ohio, 54 African American and white youth were diagnosed with type 2 diabetes between 1982 and 1994.[14] From a 1982 annual rate of 0.7 per 100,000, the incidence of type 2 diabetes in the age group 10 to 19 years increased to 1.2 per 100,000 in 1992, then jumped to 7.2 per 100,000 in 1994. Among 0- to 19-year-olds, type 2 diabetes accounted for 2% to 4% of all new cases of diabetes in the years 1982 to 1992, but for 16% in 1994. Among 10- to 19-year-olds, type 2 diabetes accounted for 3% to 10% of the new cases in the years 1982 to 1992, but for 33% in 1994.

In the other case reports, incidence could not be calculated because the size of the population served by the hospitals or clinics was not provided. By 1997, in a pediatric diabetes clinic in Charleston, South Carolina, 97 African Americans aged 0 to 19 years were diagnosed with diabetes; 45 (46%) had type 2 diabetes.[16] In a Little Rock, Arkansas, pediatric care center, between 1988 and 1995, 50 white, Hispanic, and African American children aged 0 to 19 years were diagnosed with type 2 diabetes.[17] Between 1988 and 1991, just 1 to 3 patients were diagnosed annually, but between 1992 and 1995, the annual figure rose to 6 to 17. At 2 referral hospitals in San Diego, California, 13 white, Hispanic, and African American youth aged 0 to 16 years were diagnosed with type 2 diabetes in 1993 and 1994; these 13 cases accounted for 8% of all new diabetes cases.[19] At a major referral center in San Antonio, Texas, between 1990 and 1997, 101 youth (17 whites and 84 Hispanics) were diagnosed with type 2 diabetes.[20] Just one case was diagnosed in 1990, but 30 cases were diagnosed in 1997. Incident cases of type 2 diabetes represented 18% of all new cases of diabetes from 1990 to 1997. A pediatric clinic serving low-income Mexican-Americans in Ventura, California, cared for 17 Hispanic youth with type 2 diabetes aged 0 to 17 years between the years 1990 and 1994, and 14 of these 17 were newly diagnosed.[21] Type 2 diabetes accounted for 45% of the incident cases of diabetes.

Characteristics of Patients with Type 2 Diabetes

Characteristics of 578 youth diagnosed with type 2 diabetes were available from 6 US case series for whites, African Americans, and Hispanics; from one registry of type 1 diabetes; and from 3 reports for American Indians and First Nation People (Table II). About 94% of the children and adolescents belonged to minority communities. Similarly, minorities were overrepresented in most of these reports relative to their population size.[14,17,19-21] Mean age at diagnosis was close to the age of puberty (approximately 12 to 14 years), except among the Pima Indians, in whom it was 16 years of age.[12] Only a few patients were younger than 10 years old at diagnosis, and the youngest was a 4-year-old Pima Indian child.[11] More patients were girls than boys.[5,9,12,14,15,17,19,20] Obesity, a family history of diabetes, and acanthosis nigricans[14,15,17,19,20] were common among patients with diabetes. Among non-Native populations, only a few cases were diagnosed by screening.[14,21] Most of the patients had been referred because of symptoms or acute illness[14,21]; others were referred because of the presence of glycosuria during urine testing for school, sports, or employment medical examinations.[14] Vaginal moniliasis was a chief complaint in one study and was reported in 24% of girls[14]; weight loss and ketosis were common, and ketoacidosis was also reported.[5,9,14,15,17,19-21] Among Pima Indian youth, both low and high birth weight, maternal diabetes during pregnancy (either gestational or type 2 diabetes), and bottle-feeding from birth were associated with type 2 diabetes.[11]

At diagnosis, insulin and C-peptide concentrations were generally elevated,[5,12,14,15,17,19-21] and islet cell antibodies were generally absent.[5,12,14,19,21] Glycosylated hemoglobin levels were lower among Pima Indians (6%)[12] at

diagnosis than in other groups (10%-13%).[5,9,15,17,21] This may be because the Pima Indians are diagnosed earlier through systematic screening. Seventeen[14] to thirty-two percent[17] of the youth with type 2 diabetes had hypertension, and 4%[14] to 32%[12] had high triglyceride concentrations at diagnosis. In one study 6% had sleep apnea and 8% had symptoms of depression or eating disorders.[14] Among Pima Indians, 22% had abnormal urine albumin excretion at diagnosis (albumin/creatinine ratio ≥30 mg/g creatinine).[12]

Among the few prospective studies available, follow-up ranged from 6 months to 10 years.[5,12,15,19,21] In general, glucose control was poor after diagnosis, as evidenced by mean glycosylated hemoglobin values of 10% to 13%.[5,12,15,21] A Pima Indian study provided a mean follow-up of 10 years for 36 tribe members.[12] At a median age of 26 years at follow-up, microalbuminuria and macroalbuminuria (albumin/creatinine ratio ≥300 mg/g) were present in 58% and 16% of the patients, respectively. Hypertension was present in 14%, hypercholesterolemia (>200 mg/dL) in 30%, and hypertriglyceridemia (>200 mg/dL) in 55% of patients. Among other ethnic groups, a few cases with severe complications (eg, renal insufficiency) have been reported (Dean H, presentation at CDC workshop, Jan 1999).[19,21]

Public Health Importance of Type 2 Diabetes Among Children and Adolescents

When is a disease a public health problem? Using our epidemiologic review, we applied the criteria suggested by Vinicor[22] to consider type 2 diabetes as a public health problem among North American youth.

Does Type 2 Diabetes Affect a Significant Proportion of Children and Adolescents?

For American Indians, this first criterion is met. For the age group 15 to 19 years, recent prevalence estimates of type 2 diabetes obtained from outpatient clinic reports ranged from 2.3/1000 (Canadian Cree and Ojibwa in Manitoba[6]) to 4.5/1000 (US American Indians)[13] to 50.9/1000 (US Pima Indians from active population screening).[12] By comparison, the prevalence of type 1 diabetes in US residents aged 0 to 19 years is 1.7/1000.[29]

The magnitude of the problem in other major ethnic groups is not as clear. Few population-based prevalence estimates were available, and the small numbers of persons screened and diagnosed in these studies made the estimates imprecise. Nevertheless, in case reports limited to the 1990s, type 2 accounted for 8% to 45% of all new pediatric cases of diabetes (types 1 and 2). The 1994 incidence for type 2 diabetes of 7.2/100,000 (ages 10 to 19 years) from the Cincinnati study[14] could also be compared with the annual incidence of type 1 diabetes reported by the Allegheny registry for a similar population (19/100,000; Ingrid Libman, personal communication).

While comparing the incidence of the 2 types of diabetes, it may be useful to point out that a substantial proportion of type 2, and probably not type 1, may be misclassified, undiagnosed, or unreported. First, it seems likely that when patients with type 2 diabetes present with severe symptoms, they are often diagnosed as having type 1 diabetes, as strongly suggested for Hispanics and African Americans by registry data.[26-28] It is indeed known that African American adolescents may present with severe ketoacidosis and a transient insulin requirement.[15] On the other hand, we believe that most of the cases reported in this review as type 2 diabetes were correctly classified. Characteristics of children were very similar to characteristics used to classify adults as having type 2 diabetes.[1] Some, but not all, the case definitions required immune markers to be absent[5,12,14,19,21] and insulin and C-peptide concentrations to be either normal or elevated rather than reduced.[5,12,14,15,17,19-21]

Second, it is well known that undiagnosed type 2 diabetes, and not type 1 diabetes, is very common among adults.[1] However, in the pediatric case reports, most of the children were diagnosed as having type 2 diabetes because they complained about symptoms,[9,14,15,17,20,21] and the average glycosylated hemoglobin level was as high as 10% to 13%.[5,9,15,17,21] Third, all the case reports we reviewed were described by pediatric endocrinologists, which might partially explain the mean age at diagnosis of 12 to 14 years in those reports. In contrast, the average age was 16 years among Pima Indians diagnosed by systematic screening,[12] which emphasizes the possibility of undiagnosed or unreported type 2 diabetes among adolescents. For example, in the Cincinnati study, there were actually 66 pediatric patients with type 2 diabetes, but 12 were not referred to the main pediatric center and thus not reported.[14]

Studies have underestimated the problem in many ways. Nonetheless, diagnosed type 2 diabetes in certain pediatric populations may not lag far behind the prevalence of type 1, which is already considered one of the most prevalent pediatric chronic diseases in the United States.[29]

Is Type 2 Diabetes Among Children and Adolescents on the Increase?

An increase in the prevalence of type 2 diabetes is clearly evident among Pima Indian children and adolescents[11]; in addition, Indian Health Service data demonstrate a recent significant increase in the prevalence of diabetes among US American Indian youth, as identified by use of health services.[13] Less is known about other ethnic groups. However, the recent increases in type 1 diabetes among African American and Hispanic adolescents reported by two US registries might reflect a rise in the incidence of pediatric type 2 diabetes, because misclassification as type 1 appears to be common.[26-28]

Theoretically, a secular increase could be an artifact of improved screening,

case ascertainment, and reporting. The disease may also become more symptomatic at onset, which may be due to an increase in extreme obesity and insulin resistance. However, these factors cannot explain the increasing prevalence in population-based studies in which systematic screening is used.

On the other hand, there is evidence that recognized major risk factors for type 2 diabetes among adults are currently prevalent in youth and have recently increased. First, obesity has dramatically increased among US youth across all ages and ethnic groups,[30] and the prevalence of physical inactivity is also substantial.[31] Second, maternal diabetes during pregnancy has been linked among the Pima Indians to the development of type 2 diabetes in the offspring.[11] As a younger age at onset of diabetes has been reported,[8] a potential secular increase in prevalence of diabetes among women of childbearing age might be responsible for an increasing prevalence of pediatric type 2 diabetes. The Pima Indian data also suggested that children with low birth weight were at risk for type 2 diabetes,[11] and survival of these children improved over the years. Third, impaired glucose tolerance, a pre-diabetic state among adults, may have become more prevalent among children and adolescents, but data to assess this are lacking. Finally, minority populations are expected to grow at a much faster rate than the white population. By the year 2030, more than half of all US adolescents will be members of minority groups, which are populations at risk for type 2 diabetes. For all these reasons, a true rise in pediatric type 2 diabetes may indeed be occurring.

Does Type 2 Diabetes Among Children and Adolescents Impose a Large Burden on the Population?

Much of the future population burden from type 2 diabetes in children and adolescents will result from complications such as cardiovascular diseases, retinopathy, neuropathy, and nephropathy. Correspondingly, an earlier age at onset will lead to an earlier onset of diabetic complications, and an onset close to the age of puberty adds special challenges for treatment and follow-up. Preliminary data have demonstrated poor glucose control among teenagers.[5,12,15,21] Data from Pima Indian children and adolescents have shown a clustering of cardiovascular risk factors and diabetic complications (eg, lipid abnormalities, high blood pressure, microalbuminuria or macroalbuminuria) at diagnosis and at follow-up.[12]

The 1988 National Health Interview Survey demonstrated the severe consequences of chronic diseases on health status, development, learning abilities, behavioral and emotional functions, and health service utilization for children and adolescents.[32] More specifically, type 1 diabetes ranked among the leading childhood chronic diseases in its effects on limitations in usual activities, school absence, days spent in bed, use of medications, hospitalizations, and physician contacts. Type 2 diabetes is likely to follow the same patterns. Type 2 diabetes is also associated with multiple co-morbidities, and children who have multiple conditions of a chronic nature have been reported in the same survey to have increased morbidity across those measurements. Thus the long-term consequences of type 2 diabetes may be even more devastating in youth than those of type 1 diabetes.

Are the Needs of the Affected Population Important and of Public Concern?

The realization that type 2 diabetes, already a serious adult disease, now affects children and adolescents has generated much public concern, especially in the media. The media have stressed that type 2 diabetes is linked to the way we live, and the public may well conclude that the disease reflects societal patterns favoring obesity and physical inactivity. Public concern will also be raised by the realization that type 2 diabetes is a costly disease, and its high costs will escalate because of the growing burden among younger persons, with the subsequent loss of their productivity as adults because of premature morbidity.

An increase in the prevalence of type 2 diabetes in youth should be of particular concern, considering the disparities in adult type 2 diabetes, general health status, and access to care that already exist by ethnicity and socioeconomic status. This is another compelling argument that diabetes and its complications have a legitimate public health dimension.[22]

Is It Feasible to Act on Type 2 Diabetes Among Children and Adolescents at a Community or Public Health Level?

Among children and adolescents, type 2 diabetes is probably as closely linked to modifiable risk factors such as obesity, poor nutrition, and physical inactivity as it is among adults.[1] Childhood and adolescence are periods when behaviors are established. Increasing physical activity and reducing obesity can reduce the incidence of type 2 diabetes and also help to prevent other chronic diseases. Thus a public health approach to prevention of type 2 diabetes and its risk factors, which targets all children and adolescents and their environment (eg, media, school, community, family), should improve health at the population level. Additional approaches could target those at high risk for type 2 diabetes. In recent years, community and school interventions targeting youth have begun to promote physical activity and improved diet,[33] but the long-term effectiveness of these programs is not yet established.

Even though primary prevention would be ideal, one should not ignore the evidence that several efficacious secondary prevention strategies for adult type 2 diabetes exist, including glucose, lipid, and blood pressure con-

trol and aspirin treatment. Because an earlier age at onset increases the lifetime incidence of diabetic complications, interventions in younger populations are likely to be most cost-effective.[34] The efficacy of insulin treatment for intensive glucose control has also been demonstrated for adolescents with type 1 diabetes,[35] but not for those with type 2 diabetes. However, hypoglycemic drugs other than insulin have not been tested and approved for youth with type 2 diabetes. In addition, population mobility, lack of symptoms and denial, absence of family support, and inadequate health care insurance coverage may be major barriers to adherence to treatment and follow-up and to successful clinical management. Thus there is large potential for improving the current health care management of type 2 diabetes among North American children and adolescents.

CONCLUSION

Type 2 diabetes has already become a sizable public health problem among American Indian and First Nation youth in the United States and Canada. It may also be a substantial problem in other populations of North American youth who have not been as well studied. We need a much better understanding of the magnitude, characteristics, and consequences of this disease in youth, as well as standard case definitions for epidemiologic, surveillance, and clinical purposes. Clinicians face many barriers in devising treatment plans for youth diagnosed with type 2 diabetes. Focusing efforts to prevent complications and disabilities on those children who already have the disease makes public health sense. The ideal approach would, however, include a broader public health approach to preventing risk factors for chronic disease among youth from all ethnic groups.[33] Type 2 diabetes among youth may be the first consequence of the epidemic of obesity observed among North American youth from all ethnic groups.

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REFERENCES

1. 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 1999;22(suppl 1):S5-S19.
2. Savage PJ, Bennett PH, Senter G, Miller M. High prevalence of diabetes in young Pima Indians. Evidence of phenotypic variation in a genetically isolated population. Diabetes 1979;28: 837-42.
3. Young TK, McIntyre LL, Dooley J, Rodriguez J. Epidemiologic features of diabetes mellitus among Indians in northwestern Ontario and northeastern Manitoba. Can Med Assoc J 1985; 132:793-7.
4. Dean HJ, Moffatt MEK. Prevalence of diabetes mellitus among Indian children in Manitoba. Arctic Med Res 1988;47:532-4.
5. Dean HJ, Mundy RL, Moffatt M. Non-insulin-dependent diabetes mellitus in Indian children in Manitoba. Can Med Assoc J 1992;147:52-7.
6. Dean HJ. NIDDM-Y in First Nation children in Canada. Clin Pediatr 1998; 39:89-96.
7. Dean HJ, Young TK, Flett B, Wood-Steinman P. Screening for non-type 2 diabetes in aboriginal children in northern Canada [letter]. Lancet 1998; 352:1523-4.
8. Fox C, Harris SB, Whalen-Brough E. Diabetes among Native Canadians in Northwestern Ontario: 10 years later. Chronic Dis Can 1994;15:92-6.
9. Harris SB, Perkins BA, Whalen-Brough E. Non-insulin-dependent diabetes mellitus among First Nations children. Can Fam Physician 1996;42:869-76.
10. Harris SB, Gittelsohn J, Hanley A, Barnie A, Wolever T, Gao J, et al. The prevalence of NIDDM and associated risk factors in Native Canadians. Diabetes Care 1997;20:185-7.
11. Dabelea D, Hanson RL, Bennett PH, Roumain J, Knowler WC, Pettitt DJ. Increasing prevalence of type 2 diabetes in American Indian children. Diabetologia 1998;41:904-10.
12. Fagot-Campagna A, Knowler WC, Pettitt DJ. Type 2 diabetes in Pima Indian children: cardiovascular risk factors at diagnosis and 10 years later [abstract]. Diabetes 1998; 47(suppl 1):A155.
13. Rios Burrows N, Acton K, Geiss L, Engelgau M. Trends in diabetes prevalence among American Indian and Alaska Native children, adolescents, and young adults, 1991-1997. 11th Annual Indian Health Service Research Conference 1999; 1999 Apr 26-28; Albuquerque, New Mexico. Albuquerque: Indian Health Service; 1999. p. 19.
14. Pinhas-Hamiel O, Dolan LM, Daniels SR, Standford D, Khoury PR, Zeitler P. Increased incidence of non-insulin-dependent diabetes mellitus among adolescents. J Pediatr 1996;128:608-15.
15. Willi SM, Mcburney P, Kennedy A, Wojciechowski B, Garvey T. Ketosis-prone NIDDM in African-American children [abstract]. Diabetes 1997;46 (suppl 1):A67.
16. Willi SM, Kennedy A, Wojciechowski B, Garvey T. Insulin resistance and defective glucose-insulin coupling in ketosis-prone type 2 diabetes of African-American youth [abstract]. Diabetes 1998; 47(suppl 1):A306.
17. Scott CR, Smith JM, Cradock MM, Pihoker C. Characteristics of youth-onset noninsulin-dependent diabetes mellitus and insulin-dependent diabetes mellitus at diagnosis. Pediatrics 1997;100:84-91.
18. Pihoker C, Scott CR, Lensing SY, Cradock MM, Smith J. Non-insulin dependent diabetes mellitus in African-American youths of Arkansas. Clin Pediatr 1998;37:97-102.
19. Glaser NS, Jones KL. Non-insulin-dependent diabetes mellitus in Mexican-American Children. West J Med 1998; 168:11-6.
20. Hale DE, Danney KM. Non-insulin dependent diabetes in Hispanic youth (type 2Y) [abstract]. Diabetes 1998;47 (suppl 1):A82.
21. Neufeld ND, Raffel LJ, Landon C, Chen Y-DI, Vadheim CM. Early pre-

sentation of type 2 diabetes in Mexican-American youth. Diabetes Care 1998;21:80-6.
22. Vinicor F. Is diabetes a public-health disorder? Diabetes Care 1994;17 (suppl 1):22-7.
23. Freedman DS, Serdula MK, Percy CA, Ballew C, White L. Obesity, levels of lipids and glucose, and smoking among Navajo adolescents. J Nutr 1997;127(suppl):2120-7S.
24. Delisle HF, Ekoe JM. Prevalence of non-insulin-dependent diabetes mellitus and impaired glucose tolerance in two Algonquin communities in Quebec. Can Med Assoc J 1993;148:41-7.
25. Batey LS, Goff DC, Tortolero SR, Nichaman MZ, Chan W, Chan FA, et al. Summary measures of the insulin resistance syndrome are adverse among Mexican-American versus non-Hispanic white children. The Corpus Christi Child Heart Study. Circulation 1997;96:4319-25.
26. Libman IM, LaPorte RE, Becker D, Dorman JS, Drash AL, Kuller L. Was there an epidemic of diabetes in nonwhite adolescents in Allegheny County, Pennsylvania? Diabetes Care 1998; 21:1278-81
27. Lipton R, Onyemere K, Silverman B. Age and ethnic differences in ten-year incidence of insulin-treated diabetes in urban African American and Latino children [abstract]. Diabetes 1998;47 (suppl 1):A146.
28. Onyemere K, Lipton R, Baumann E, Silverman B, Brodsky I. Onset features of insulin-treated atypical type 1 and early onset type 2 diabetes in African American and US Latino children [abstract]. Diabetes 1998;47 (suppl 1):A25.
29. LaPorte RE, Matsushima M, Chang YF. Prevalence and incidence of insulin-dependent diabetes. In: Harris MI, Cowie CC, Stern MP, Boyko EJ, Reiher GE, Bennett PH, editors. Diabetes in America. 2nd ed. Washington (DC): National Institutes of Health, NIDDK; 1995. p. 37-46.
30. Troiano RP, Flegal KM, Kuczmarski RJ, Campbell SM, Johnson CL. Overweight prevalence and trends for children and adolescents. The National Health and Nutrition Examination Surveys, 1963 to 1991. Arch Pediatr Adolesc Med 1995;149:1085-91.
31. US Department of Health and Human Services. Physical activity and health: a report of the Surgeon General. Atlanta (GA): US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996. p. 186-207.
32. Newacheck PW, Taylor WR. Childhood chronic illness: prevalence, severity, and impact. Am J Public Health 1992;82:364-71.
33. Fagot-Campagna A, Rios Burrows N, Williamson DF. The public health epidemiology of type 2 diabetes in children and adolescents: a case study of American Indian adolescents in the southwestern United States. Clin Chim Acta 1999;286:81-95.
34. CDC Diabetes Cost-effectiveness Study Group. The cost-effectiveness of screening for type 2 diabetes. J Am Med Assoc 1998;20:1757-63.
35. Diabetes Control and Complications Trial Research Group. Effects of intensive diabetes treatment on the development and progression of long-term complications in adolescents with insulin-dependent diabetes mellitus: Diabetes Control and Complications Trial. J Pediatr 1994;125:177-88.