Incidence of Diabetes in Youth in the United States

The Writing Group for the SEARCH for Diabetes in Youth Study Group*

ESTIMATES OF THE INCIDENCE OF type 1 diabetes mellitus (DM) derived from population-based registries show an increase in incidence worldwide during the past 2 decades,[1-7] albeit less so in the United States.[8,9] It has been assumed that type 1 DM identified in these registries is mostly autoimmune-mediated, although this has not been confirmed with measured diabetes autoantibodies.

Type 2 DM has traditionally been viewed as a disorder of adults, most commonly observed in those persons who are middle-aged or elderly. Indeed, onset of DM after 30 or 40 years has frequently been used to distinguish type 2 from type 1 DM. However, as the prevalence of obesity has increased in recent decades, several studies have reported an increasing proportion of youth with apparent type 2 DM, especially among racial/ethnic minority populations.[10,11] The number of population-based studies is small,[12] many were conducted among American Indians,[13-15] and most used a clinical DM definition.[16,17]

There are currently limited comprehensive population-based estimates of DM incidence among US youth covering all major racial/ethnic

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Context Data on the incidence of diabetes mellitus (DM) among US youth according to racial/ethnic background and DM type are limited.

Objective To estimate DM incidence in youth aged younger than 20 years according to race/ethnicity and DM type.

Design, Setting, and Participants A multiethnic, population-based study (The SEARCH for Diabetes in Youth Study) of 2435 youth with newly diagnosed, nonsecondary DM in 2002 and 2003, ascertained at 10 study locations in the United States, covering a population of more than 10 million person-years.

Main Outcome Measure Incidence rates by age group, sex, race/ethnicity, and DM type were calculated per 100 000 person-years at risk. Diabetes mellitus type (type 1/type 2) was based on health care professional assignment and, in a subset, further characterized with glutamic acid decarboxylase (GAD65) autoantibody and fasting C peptide measures.

Results The incidence of DM (per 100 000 person-years) was 24.3 (95% confidence interval [CI], 23.3-25.3). Among children younger than 10 years, most had type 1 DM, regardless of race/ethnicity. The highest rates of type 1 DM were observed in non-Hispanic white youth (18.6, 28.1, and 32.9 for age groups 0-4, 5-9, and 10-14 years, respectively). Even among older youth (≥10 years), type 1 DM was frequent among non-Hispanic white, Hispanic, and African American adolescents. Overall, type 2 DM was still relatively infrequent, but the highest rates (17.0 to 49.4 per 100 000 person-years) were documented among 15- to 19-year-old minority groups.

Conclusions Our data document the incidence rates of type 1 DM among youth of all racial/ethnic groups, with the highest rates in non-Hispanic white youth. Overall, type 2 DM is still relatively infrequent; however, the highest rates were observed among adolescent minority populations.

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groups and DM types. The SEARCH for Diabetes in Youth Study has been specifically designed to identify incident cases of DM among individuals younger than 20 years to estimate the population incidence of type 1, type 2, and other types of DM overall and by age and race/ethnicity. We report herein incidence estimates of DM in youth for the 2002-2003 period by age group, sex, DM type, and race/ethnicity.

METHODS
Structure of the SEARCH Incidence Study
The SEARCH study is a multicenter observational study conducting popula-

tion-based ascertainment of cases of physician-diagnosed DM in youth aged younger than 20 years.[18] New DM cases occurring in 2002 and 2003 were identified (1) in geographically defined populations in Ohio, Washington, South Carolina, and Colorado; (2) among health plan enrollees in Hawaii (Hawaii Medical Service Association, Med-Quest, Kaiser Permanente Hawaii) and California (Kaiser Permanente Southern California, excluding San Diego); and (3) with coordination by the Colorado center, among health service beneficiary rolls in 3 American Indian reservation-based populations in Arizona and New Mexico, and among participants in the National Institute of Diabetes and Digestive and Kidney Diseases Pima Indian study in Arizona.[19]

Incidence Study Population

The denominator included noninstitutionalized, nonmilitary youth aged younger than 20 years in the index year. Because the 2000 US Census projections for youth residing in the participating areas were similar in 2002 and 2003 (−0.2% change overall), the same denominator was used for both years. The study covered 10 031 888 person-years at risk, which represents 6.2% of the US population younger than 20 years. Derivation of the appropriate denominators was a multistep process taking into account racial/ethnic categorization and the civilian nature of the study population.[20] For the geographically based sites, nonmilitary age-, sex-, and race/ethnicity-specific denominators were determined based on projections from the 2000 US Census (http://www.cdc.gov/nchs/about/major/dvs/popbridge/popbridge.htm). For California, race/ethnicity-, age-, and sex-specific denominators were based on block-level geocoding of the health plan membership.[21] For Hawaii, racial/ethnic denominators were based on proportional distributions from the US Census for the health plan catchment area. For the American Indian reservation-based populations, denominators were defined by the health service user population for the eligible ser-

vice units or by participation in the research study. A race-bridging model[22] was used to classify persons with at least 2 self-reported races into larger categories. Race/ethnicity-specific estimates were pooled across sites using 5 categories: non-Hispanic white, Hispanic, African American, Asian/Pacific Islander, and American Indian.

The numerator included all youth with nongestational DM newly diagnosed in 2002 and 2003 who were younger than 20 years on December 31 of the index year. The case ascertainment approach involved networks of pediatric and adult endocrinologists, existing pediatric DM databases, hospitals, health plan databases, and other health care organizations.[18] Geographic-based centers established active surveillance systems de novo. The American Indian reservation-based populations used existing DM databases as the source for case identification. In addition to reporting of cases by pediatric endocrinologists, the membership-based sites identified cases using information from linkage of computer data on prescriptions, hospitalization with DM as the discharge diagnosis, and laboratory measures of glycated hemoglobin A_{1c}.

Case Validation and Collection of Core Variables

All case reports were validated on the basis of physician reports or medical record reviews, or self-report of a physician diagnosis of DM in 60 cases. A physician-diagnosed case of DM was established if any of the following criteria were met: (1) medical record review indicated a physician diagnosis of DM, (2) the diagnosis of DM was directly verified by a physician, (3) the physician referred a youth with DM to the study, or (4) the case was included in a clinical database that had a requirement for verification of diagnosis of DM by a physician. For all validated cases, core demographic and diagnostic information, including date of birth, sex, race/ethnicity, date of diagnosis, and DM type, were obtained from medical records, usually as part of the case validation process. Date of birth,

sex, and date of diagnosis were available on all cases. The clinical DM type assigned by the health care professional was obtained from medical records or physician reports and categorized as follows: (1) type 1 (combining type 1, type 1a, and type 1b), (2) type 2, and (3) other types (including hybrid type, maturity onset diabetes of the young, secondary DM, type unknown by the reporting source, type designated as other, and missing type). Race/ethnicity was based on self-report or medical record–based data for 95.9% of cases, and on US Census block-level geocoding for the 4.1% cases with missing race/ethnicity. All validated case reports together with the corresponding core variables described above were registered anonymously with the coordinating center at Wake Forest University in North Carolina.

Additional Data Collection

In addition to the case validation process and collection of core variables, youth with nonsecondary DM identified by SEARCH were asked to participate in a research visit that included study-specific questionnaires, a brief physical examination, and a blood draw.[23] The questionnaires collected information on participant's medical history and comorbid conditions, health services utilization, insurance, and satisfaction with medical care. Blood was drawn for measurement of glutamic acid decarboxylase antibodies and fasting C peptide levels, which were used to further characterize the clinically assigned DM type. Of the 2435 cases invited to the visit, 1134 (46%) had measurements of glutamic acid decarboxylase antibodies and fasting C peptide levels. The visit occurred after an overnight fast, under conditions of metabolic stability, defined as no episode of diabetic ketoacidosis during the previous month. All medicines, except long-acting insulin, were discontinued the night before the visit. Mean (SD) DM duration at the visit was 11.74 (7.25) months and was similar for subgroups of race/ethnicity and DM type.

Table 1. Number of Youth With Nonsecondary DM (2002-2003), Population Denominators, and Incidence Rates by Age Group, Sex, and Race/Ethnicity

Characteristics	No. of Youth With DM*	Population Denominator, Person-Years	Incidence Rate per 100 000 Person-Years (95% CI)
Total population	2435	10 031 888	24.3 (23.3-25.3)
Age group, y			
0-4	345	2 405 348	14.3 (12.9-15.9)
5-9	560	2 446 750	22.9 (21.1-24.9)
10-14	903	2 661 278	33.9 (31.8-36.2)
15-19	627	2 518 512	24.9 (23.0-26.9)
Sex			
Male	1193	5 123 956	23.3 (22.0-24.6)
Female	1242	4 907 932	25.3 (23.9-26.8)
Race/ethnicity†			
Non-Hispanic white	1545	5 928 400	26.1 (24.8-27.4)
African American	365	1 434 750	25.4 (23.0-28.2)
Hispanic	323	1 603 502	20.2 (18.1-22.5)
Asian/Pacific Islander	131	780 110	16.7 (14.1-19.9)
American Indian	71	285 126	25.0 (19.8-31.5)

Abbreviations: CI, confidence interval; DM, diabetes mellitus.
*Includes 1905 youth with type 1 DM and 530 youth with type 2 DM.
†Based on self-report or medical record–based data for 95.9% of cases, and on US Census block-level geocoding for the 4.1% cases with missing race/ethnicity.

Blood specimens were processed locally and shipped within 24 hours to the central laboratory (University of Washington, Seattle). Samples were analyzed for glutamic acid decarboxylase antibodies in radioligand-binding assays.[24,25] The levels were expressed as a glutamic acid decarboxylase antibodies index: counts per minute (cpm) of the unknown sample minus average cpm of 2 negative standards divided by cpm of the positive standard minus average of 2 negative standards. Fasting C peptide levels were measured by radioimmunoassay.[26] The assay precision had a coefficient of variation between 6.6% and 10.7%, and a sensitivity limit of 0.15 ng/mL.

The study was approved by the appropriate institutional review boards and recruitment of participants followed procedures compliant with the Health Insurance Portability and Accountability Act. All parents or participants that came to the in-person visit signed age-appropriate informed consent or assent forms.

Statistical Analyses

Completeness of case ascertainment was assessed for 2002 for geographically based centers using the capture-recapture method[27] and a 2-mode ascertainment model (hospital vs health care professional). For each center, cases were identified from multiple sources (from 13 to 41). A source was defined as any location in which cases were reported. Matching across sources to identify potential duplicate records was performed on a regular basis at the center level using available personal health identifiers. Once matching across sources was accomplished, the sources were further grouped into 2 modes of ascertainment (health care professionals and inpatient hospital system records). The percentage completeness of ascertainment for each site was taken as the number of observed cases divided by the number estimated from the capture-recapture method. Estimates of the ascertainment rates pooled across clinical sites were produced from a global log-linear model,[28] which allowed for separate intrasite performance. The rates were estimated using maximum likelihood and the SEs used the δ method.[29] Approximately 20% of the study population was ascertained in membership-based sites where it was impossible to assess completeness of ascertainment using capture-recapture analyses due to the lack of independent sources of case ascertainment.

Incidence rates by age group, sex, race/ethnicity, and clinical DM type were calculated per 100 000 person-years at risk. Ninety-five percent confidence intervals (CIs) were calculated on the basis of inverting the score test for a binomial proportion.[30] All statistical analyses were performed by using SAS version 9.0 (SAS Institute Inc, Cary, NC). $P<.05$ was considered statistically significant.

RESULTS

A total of 2561 newly diagnosed patients aged younger than 20 years in 2002 (n=1325) and 2003 (n=1236) were ascertained, which included 1905 youth with type 1 DM, 530 youth with type 2 DM, and 126 youth with other DM types (62 youth with secondary forms of DM and 64 youth with other or hybrid types or unknown or missing information on DM type). Cases were ascertained at sites covering populations of varying sizes (Ohio: 355 cases among 1.1 million population; South Carolina: 539 among 2.2 million; Washington: 509 among 1.9 million; Colorado: 655 among 2.5 million; American Indian reservations: 58 among 200 000; California: 342 among 1.5 million; and Hawaii: 103 among 500 000). Completeness of ascertainment was estimated to be 93% across all 4 geographically based sites and varied little with site (from 87% to 99%). Ascertainment was lower among the 15- to 19-year-old group (87%) than among the 0- to 4-year-old (95%), 5- to 9-year-old (94%), and 10- to 14-year-old (93%) age groups.

A total of 2435 youth with nonsecondary DM newly diagnosed in 2002-2003 were identified across all study locations in a population of more than 10 million person-years (**TABLE 1**). Overall, the incidence rate (per 100 000 person-years) of DM was 24.3 (95% CI, 23.3-25.3). The incidence rate was highest among 10- to 14-year-old youth (33.9; 95% CI, 31.8-36.2), and slightly higher in females vs males (25.3; 95% CI, 23.9-26.8; vs 23.3; 95% CI, 22.0-24.6). Overall, the highest incidence rates of DM were observed among non-Hispanic white (26.1; 95% CI, 24.8-27.4), African American (25.4; 95% CI, 23.0-28.2), and American Indian youth (25.0; 95% CI, 19.8-31.5), with lower

rates among Hispanic (20.2; 95% CI, 18.1-22.5) and Asian/Pacific Islander youth (16.7; 95% CI, 14.1-19.9).

TABLE 2 shows incidence estimates (per 100 000 person-years) of DM by 5-year age groups, race/ethnicity, and DM type (type 1 and type 2). For children aged 0 to 4 years and 5 to 9 years, most DM was type 1, regardless of race/ethnicity. The incidence of type 1 DM was highest among non-Hispanic white children (18.6 for 0-4 years and 28.1 for 5-9 years), and lowest among American Indian (4.1 and 5.5, respectively) and Asian/Pacific Islander children (6.1 and 8.0, respectively), with intermediate rates among Hispanic (9.1 and 15.7, respectively) and African American children (9.7 and 16.2, respectively). No children aged 0 to 4 years and only 19 children aged 5 to 9 years had type 2 DM.

Similarly, for older youth (10-14 years and 15-19 years), the incidence of type 1 DM (per 100 000 person-years) was highest among non-Hispanic white children (32.9 and 15.1, respectively), followed by African American (19.2 and 11.1, respectively) and Hispanic youth (17.6 and 12.1, respectively), and lowest among American Indian (7.1 and 4.8, respectively) and Asian/Pacific Islander youth (8.3 and 6.8, respectively). The rates of type 2 DM were highest among American Indian youth (25.3 for 10-14 years and 49.4 for 15-19 years), followed by African American (22.3 and 19.4, respectively), Asian/

Pacific Islander (11.8 and 22.7, respectively), and Hispanic youth (8.9 and 17.0, respectively), and were lowest among non-Hispanic white youth (3.0 and 5.6, respectively).

FIGURE 1 and FIGURE 2 show race/ethnicity-specific incidence estimates of type 1 DM and type 2 DM, respectively, by 5-year age groups and sex. The female-to-male incidence rate ratio (RR) was cal-

Table 2. Incidence Rates of Diabetes (2002-2003) per 100 000 Person-Years by Age Group, Race/Ethnicity, and Diabetes Mellitus Type

		Type 1 Diabetes		Type 2 Diabetes	
Age Group	Total No. of Youth	No. of Youth	Incidence Rate (95% CI)	No. of Youth	Incidence Rate (95% CI)
0-4 y					
Non-Hispanic white	696 338	259	18.6 (16.5-21.0)	0	0.0 (0.0-0.3)
African American	171 753	33	9.7 (6.9-13.6)	0	0.0 (0.0-1.1)
Hispanic	209 846	38	9.1 (6.7-12.5)	0	0.0 (0.0-0.9)
Asian/Pacific Islander	92 650	11	6.1 (3.5-10.9)	0	0.0 (0.0-2.1)
American Indian	32 087	3	4.1 (1.3-13.0)	0	0.0 (0.0-6.0)
All	1 202 674	345	14.3 (12.9-15.9)	0	0.0 (0.0-0.2)
5-9 y					
Non-Hispanic white	714 238	401	28.1 (25.5-31.0)	4	0.3 (0.1-0.7)
African American	173 942	56	16.2 (12.5-21.0)	6	1.7 (0.8-3.7)
Hispanic	204 809	65	15.7 (12.3-20.1)	5	1.3 (0.6-2.9)
Asian/Pacific Islander	95 675	15	8.0 (4.9-13.1)	4	2.2 (0.9-5.6)
American Indian	34 712	4	5.5 (2.1-14.5)	0	0.0 (0.0-5.6)
All	1 223 376	541	22.1 (20.3-24.1)	19	0.8 (0.5-1.2)
10-14 y					
Non-Hispanic white	787 605	518	32.9 (30.2-35.8)	47	3.0 (2.3-4.0)
African American	194 635	75	19.2 (15.4-24.1)	87	22.3 (18.1-27.5)
Hispanic	205 436	72	17.6 (14.0-22.2)	37	8.9 (6.4-12.3)
Asian/Pacific Islander	103 233	17	8.3 (5.2-13.3)	24	11.8 (7.9-17.5)
American Indian	39 729	6	7.1 (3.2-15.8)	20	25.3 (16.4-39.0)
All	1 330 638	688	25.9 (24.0-27.9)	215	8.1 (7.1-9.2)
15-19 y					
Non-Hispanic white	766 019	231	15.1 (13.2-17.1)	85	5.6 (4.5-6.9)
African American	177 045	39	11.1 (8.1-15.1)	69	19.4 (15.3-24.5)
Hispanic	181 660	44	12.1 (9.1-16.4)	62	17.0 (13.3-21.8)
Asian/Pacific Islander	98 497	13	6.8 (4.0-11.5)	45	22.7 (16.9-30.4)
American Indian	36 035	3	4.8 (1.7-13.2)	36	49.4 (35.6-68.5)
All	1 259 256	331	13.1 (11.8-14.6)	296	11.8 (10.5-13.2)

Abbreviation: CI, confidence interval.

Figure 1. Incidence of Type 1 Diabetes Mellitus by 5-Year Age Groups, Sex, and Race/Ethnicity, 2002-2003
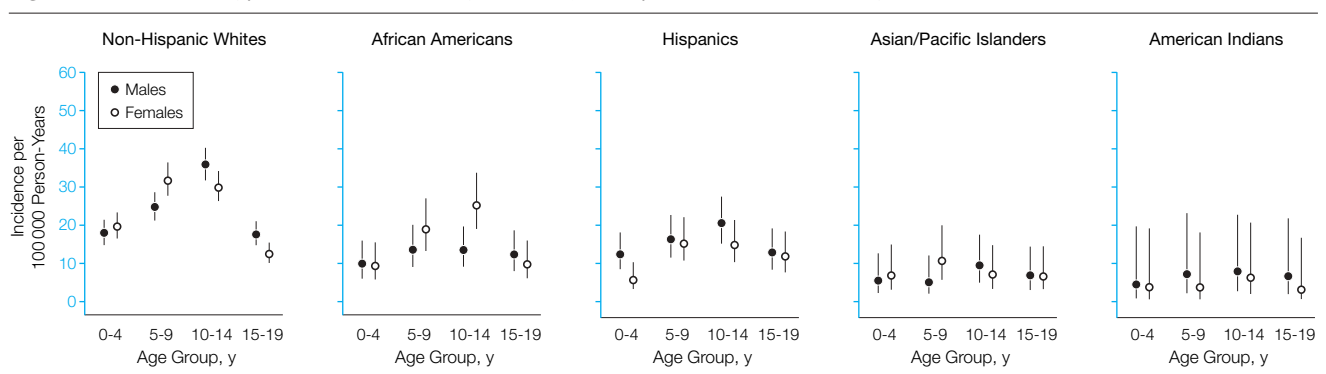
Error bars represent 95% confidence intervals. In Figures 1 and 2, y-axes in blue indicate an incidence range of 0 to 60 per 100 000 person-years.

culated with data pooled from all age groups and racial/ethnic groups, for each DM type. For type 1 DM (Figure 1), the rates were very similar in females and males (RR, 1.028; 95% CI, 1.025-1.030), although due to the large sample size, the difference reached statistical significance. Overall, across all racial/ethnic groups and sex, the highest rates of type 1 DM were observed among 5- to 9-year-old and 10- to 14-year-old youth (*P*<.001 for each age group vs 0-4 years and 15-19 years), although this was largely driven by the age pattern in non-Hispanic white youth. The incidence rate of type 2 DM (Figure 2) was higher in females than in males (RR, 1.63; 95% CI, 1.58-1.67; *P*<.001). Across all racial/ethnic groups and sex, the incidence rates of type 2 DM were higher among 15- to 19-year old youth than among 10- to 14-year-old youth (*P*<.001 for non-Hispanic whites, Hispanics, Asian/Pacific Islanders, and American Indians). This pattern was not consistent among African American youth with type 2 DM.

TABLE 3 presents the proportional distribution of type 1 and type 2 DM for each racial/ethnic group. Among youth younger than 10 years at diagnosis, most DM is type 1, regardless of race/ethnicity. Among youth aged 10 years or older at diagnosis, type 1 DM represents the major type among non-Hispanic white adolescents (85.1%). In addition, a notable proportion of minority adolescents (53.9% of Hispanic, 42.2% of African American, 30.3% of Asian/Pacific Islander, and 13.8% of American Indian) have type 1 DM. As expected, type 2 DM is most common among minorities aged 10 to 19 years, especially American Indian (86.2%) and Asian/Pacific Islander (69.7%), but also among African American (57.8%) and Hispanic (46.1%) youth.

TABLE 4 shows characteristics of youth with DM, by DM type and age group, among participants to the research visit. For both younger (<10 years) and older (≥10 years) youth, 238 (56.4%) and 330 (65.6%) participants, respectively, with a clinical di-

agnosis of type 1 DM had positive glutamic acid decarboxylase antibodies. For youth with a clinical diagnosis of type 2 DM, 1 of only 3 participants (33.3%) in the younger age group (<10 years) had positive glutamic acid decarboxylase antibodies, although in the older age group (≥10 years), 32 (21.2%) had positive glutamic acid decarboxylase antibodies. Overall, mean (SD) fasting C peptide level was significantly higher in youth with type 2 DM than in those with type 1 DM, regardless of age group (0-9 years: 1.80 (1.42) vs 0.43 (0.48) ng/mL and 10-19 years: 3.52 (2.12) vs 0.78 (0.65) ng/mL, respectively; *P*<.001 for each comparison). In addition, participants with a clinical diagnosis of type 1 DM had similar fasting C peptide levels, and similar proportions of nondetectable fasting C peptide levels (≤0.2 ng/mL [≤0.07 nmol/L]) and current insulin use, regardless of glutamic acid decarboxylase antibody status. Fasting C peptide level and current insulin use also did not substantially differ according to

Figure 2. Incidence of Type 2 Diabetes Mellitus by 5-Year Age Groups, Sex, and Race/Ethnicity, 2002-2003
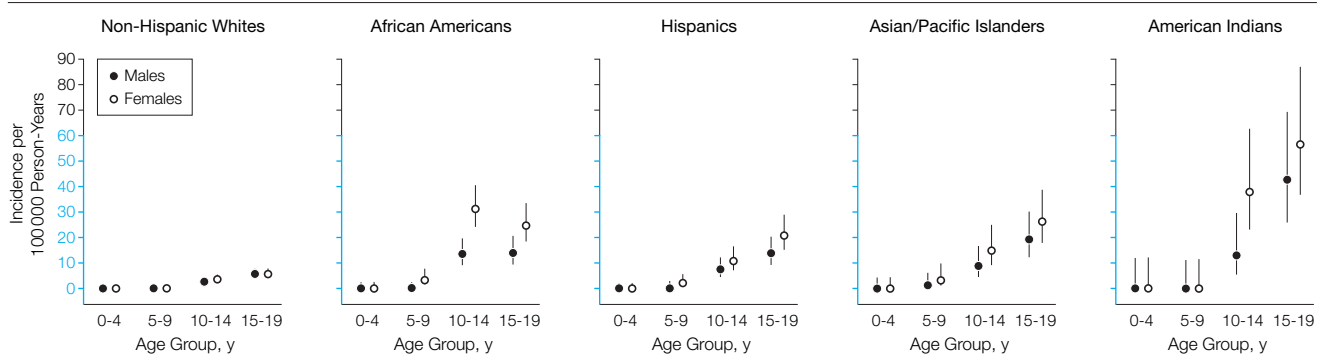
Error bars represent 95% confidence intervals. In Figures 1 and 2, y-axes in blue indicate an incidence range of 0 to 60 per 100 000 person-years.

Table 3. Proportional Distribution of Type 1 and Type 2 DM (2002-2003) by Age Group at Diagnosis and Race/Ethnicity

| | No. (%) of Youth | | | | | | | | | |
| | 0-9 y | | | | | 10-19 y | | | | |
DM	Non-Hispanic White	African American	Hispanic	Asian/Pacific Islander	American Indian	Non-Hispanic White	African American	Hispanic	Asian/Pacific Islander	American Indian
Type 1	660 (99.4)	89 (93.7)	102 (95.3)	26 (86.7)	7 (100)	749 (85.1)	114 (42.2)	116 (53.9)	30 (30.3)	9 (13.8)
Type 2	4 (0.6)	6 (6.3)	5 (4.7)	4 (13.3)	0	132 (14.9)	156 (57.8)	99 (46.1)	69 (69.7)	56 (86.2)
Total	664 (100)	95 (100)	107 (100)	30 (100)	7 (100)	881 (100)	270 (100)	215 (100)	99 (100)	65 (100)

Abbreviation: DM, diabetes mellitus.

glutamic acid decarboxylase antibody status among youth with type 2 DM.

COMMENT

With a population of more than 10 million person-years for which DM incidence is estimated, the SEARCH study represents the largest standardized registry of childhood DM in the United States. In this study, which encompasses a large multiethnic population, the vast majority of all new cases of DM in children younger than 10 years had type 1 DM, regardless of race/ethnicity. Even among older youth (≥10 years), type 1 DM is proportionately the most common form of DM for youth of non-Hispanic white and Hispanic origin. Although type 2 DM is still relatively infrequent overall, it becomes more common after 10 years of age, with higher rates among US minority populations than among non-Hispanic white populations.

The SEARCH study estimates of type 1 DM incidence are higher than the incidence of insulin-dependent DM reported for the period 1990-1994 by the Diamond Study[2] among children aged 0-4, 5-9, and 10-14 years. Our rates of type 1 DM are also 15% to 40% higher than insulin-dependent DM rates from Allegheny County, across all ages for non-Hispanic white and among 0- to 9-year-old African American children, but are lower than insulin-dependent DM rates among 10- to 19-year-old African American youth.[31] Similarly, the SEARCH study rates of type 1 DM are 30% to 80% higher than recently reported insulin-dependent DM rates from Philadelphia, across all ages for non-Hispanic white and approximately 20% higher among 0- to 9-year-old African American children, but are lower than insulin-dependent DM rates in 10- to 14-year-old African American youth.[32] Among the Hispanic population, the SEARCH study rates of type 1 DM are similar to insulin-dependent DM rates reported in the 1990s for Puerto Rican Americans from Philadelphia,[32,33] but are approximately 40% higher than those reported in the 1980s for Hispanics from Colorado.[9] Different ascertainment methods and case definitions were used in these studies, making comparisons across

studies difficult. However, taken together, these data suggest that the incidence of type 1 DM may be increasing in the United States, consistent with worldwide trends.[7,34] In agreement with previous data,[35,36] the SEARCH study shows that incidence rates of type 1 DM peak at ages 5 to 9 years and 10 to 14 years, and the risk is similar for males and females. We estimate that the annual number of newly diagnosed youth with type 1 DM in the United States is approximately 15 000.

There are limited population-based data on the incidence of type 2 DM in youth, which makes comparison with other studies difficult. Using data from the medical records of 735 African American and Latino children with type 2 DM in Chicago,[12] the incidence was higher in African American vs Latino children (5.0 per 100 000 person-years in African American girls and 2.7 per 100 000 person-years in African American boys vs 2.4 per 100 000 person-years in Latino girls and 1.8 per 100 000 person-years in Latino boys). Among 1027 consecutive patients with DM attending a diabetes clinic in Cincinnati,[17] a 10-fold increase in type 2 DM incidence rates (from 0.7 per 100 000 person-years in 1982 to 7.2 per 100 000 person-years in 1994) was observed. Among 569 children and ado-

lescents presenting to a Florida clinic with DM between 1994 and 1998,[37] the proportion with type 2 DM increased from 9.4% of new cases to 20% of new cases during the 5-year period. Consistent with previous articles,[13,38] the SEARCH study demonstrates that type 2 DM contributes considerably to the overall DM incidence among minority youth aged 10 years or older, and rates are approximately 60% higher in females than in males. Well-designed studies from Europe[39-41] indicate that type 2 DM remains a rarity in these populations, accounting for only 1% to 2% of all DM cases. In contrast, although the SEARCH study data support the notion that type 2 DM in youth is predominantly occurring in high-risk ethnic groups, type 2 DM accounts for 14.9% of all DM cases among non-Hispanic white adolescents aged 10 years or older. Although differences in obesity rates between US and European youth are likely contributors, the full explanation for these discrepancies remains uncertain. The SEARCH study estimates that the annual number of newly diagnosed youth with type 2 DM in the United States is approximately 3700.

Similar to other population-based studies,[2,13,42] these analyses focused on type 1 and type 2 DM and used DM

Table 4. Biochemical Characteristics of Youth With DM (2002-2003), by Clinical DM Type, Among Participants to the Research Visit

	Type 1 DM		Type 2 DM	
	GAD65 +	GAD65 −	GAD65 +	GAD65 −
Age 0-9 y				
No./Total No. (%)	238/422 (56.4)	184/422 (43.6)	1/3 (33.3)	2/3 (66.7)
Fasting C peptide, mean (SD), ng/mL	0.46 (0.54)	0.40 (0.38)	3.4	1.0 (0.42)
Fasting C peptide ≤0.2 ng/mL, No. (%)	135 (56.7)	106 (57.6)	0	0
Taking insulin, No. (%)	237 (99.6)	184 (100)	0	1 (50)
Age 10-19 y				
No./Total No. (%)	330/503 (65.6)	173/503 (34.4)	32/151 (21.2)	119/151 (78.8)
Fasting C peptide, mean (SD), ng/mL	0.75 (0.60)	0.82 (0.74)	2.83 (1.8)	3.71 (2.2)
Fasting C peptide ≤0.2 ng/mL, No. (%)	80 (24.2)	34 (19.7)	1 (3.1)	0
Taking insulin, No. (%)	324 (98.2)	173 (100)	14 (43.8)	37 (31.1)

Abbreviations: DM, diabetes mellitus; GAD65, glutamic acid decarboxylase antibody.
SI conversion: To convert fasting C peptide to nmol/L, multiply by 0.333.

type–assignments made by health care professionals. This raises the issue of potential variation in health care professionals' diagnostic norms across study locations. However, across all the SEARCH study sites, more than 60% of cases were reported by DM specialists (pediatric or adult endocrinologists), for which such variation is unlikely to be substantial. In addition, DM type was further characterized in a subset of youth participating in the research visit, using measurements of glutamic acid decarboxylase antibodies and fasting C peptide levels. With a clinical diagnosis of type 1 DM, glutamic acid decarboxylase antibody positivity was observed in more than 50% of individuals, regardless of age. The glutamic acid decarboxylase–negative participants with type 1 DM include patients who may have lost glutamic acid decarboxylase positivity, who may be positive for other autoantibodies, such as insulinoma-associated antibody or insulin autoantibody, who may have a form of undiagnosed monogenic DM, or other causes of insulin deficiency, as suggested by the American Diabetes Association.[43] With a clinical diagnosis of type 2 DM, and similar to other smaller US studies,[44,45] 21.2% of the SEARCH study participants aged 10 years or older had positive glutamic acid decarboxylase antibodies. The majority of participants with type 2 DM and positive glutamic acid decarboxylase antibodies were overweight (more than 75% with a body mass index, calculated as weight in kilograms divided by height in meters squared, higher than the 95th percentile), of minority racial/ethnic background (68% minorities), and more than half had glutamic acid decarboxylase antibody titers less than 2 times the cutpoint used to define positivity. This suggests that most of these participants have type 2 DM. Nevertheless, the role of DM-related autoantibody positivity in the etiology and natural evolution of DM among minority youth with a clinical phenotype of type 2 DM requires further exploration.

This study has several potential limitations. The SEARCH study did not attempt to assess how much undiagnosed DM exists among youth and did not screen for undiagnosed DM. We may, therefore, have underestimated the true risk of type 2 DM in youth; however, limited screening studies suggest that undiagnosed type 2 DM is relatively rare in youth.[46]

We used the capture-recapture method to estimate completeness of ascertainment; however, in the context of the current US health care system and privacy regulations, several limitations of the method were encountered.[27] Incomplete matching across sources due to restrictions on access to names in some sites and design of the case ascertainment system for efficiency (thus avoiding sources of likely duplicate cases) have been shown to lead to an underestimate of completeness as assessed by the capture-recapture method.[27] We therefore believe that our estimates represent the lower bound on the completeness of ascertainment in the SEARCH study. The analysis indicates a lower completeness among 15- to 19-year-old youth (87%), a group with higher incidence of type 2 DM. Had all these youth been identified, 44 more cases with type 2 DM would have been added, for an overall unadjusted rate of type 2 DM among 15- to 19-year-old adolescents of 13.5 per 100 000 person-years.

Although some of the SEARCH study centers are membership-based, their base populations are very representative of the geographic areas in which they are located. The Kaiser Permanente Southern California membership is representative of the population living in the greater Los Angeles metropolitan area with regard to demographics, ethnicity, and socioeconomic status. The Hawaii Medical Service Association, MedQuest, and Kaiser Permanente Hawaii cover more than 90% of the Hawaiian population. In addition, the capture-recapture method could not be used in the membership sites because they had essentially 1 combined reporting source for cases rather than the required 2 or more sources. However, the risk estimates (per 100 000 person-years) by age and DM type based only on the 4 geographic sites were similar to those computed with data pooled across all centers (0-9 years: for type 1 DM, 19.9 vs 18.3 per 100 000 person-years and for type 2 DM, 0.3 vs 0.4 per 100 000 person-years; and 10-19 years: for type 1 DM, 21.1 vs 19.7 per 100 000 person-years and for type 2 DM, 8.8 vs 9.9 per 100 000 person-years). This suggests that completeness of ascertainment was equally high in membership-based and geographic-based sites.

In conclusion, our data document the incidence rates of type 1 DM among youth of all racial/ethnic groups. The incidence of type 1 DM among non-Hispanic white youth now exceeds 20 per 100 000 person-years compared with 16.5 per 100 000 person-years in Allegheny County in the early 1990s.[31] Type 2 DM was found among adolescents of all racial/ethnic groups. Although the evidence of the presence of type 2 DM in youth is still developing, it is consistent with the increasing prevalence of type 2 DM in adults, and the increasing prevalence of obesity in both adults and children. Overall, type 2 DM is still relatively infrequent in US youth; however, the highest rates are observed among 15- to 19-year-old adolescent minorities, especially American Indian youth (49.4 per 100 000 person-years).

The SEARCH study provides unique population-based data on the incidence of DM among youth of various racial/ethnic backgrounds, according to DM type. Continuing this surveillance effort will document temporal trends in the incidence of DM among various racial/ethnic groups and accurately assess the future health care burden of DM and its complications in the US pediatric and young adult population.

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> While medicine is a science, in many particulars it cannot be exact, so baffling are the varying results of varying conditions of human life.
> —Charles H. Mayo (1865-1939)