

SHORT COMMUNICATION OPEN ACCESS

Risk Factors for Development of Type 2 and Prediabetes in Children During the COVID-19 Pandemic

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ABSTRACT

Background: During the COVID-19 pandemic, there was a rise in the incidence of type 2 diabetes (T2D) and prediabetes in children and teenagers. We investigated whether new risk factors for diabetes in children emerged during the pandemic period.

Methods: Using health records of a large, integrated health system, we evaluated the incidence of new-onset T2D and prediabetes in patients aged 0–19 years from 2020 to 2023. We utilised descriptive statistics, chi-square and multivariable logistic regressions to predict the risk of T2D and prediabetes.

Results: Compared to children with normal weight, children with obesity ($p < 0.0001$) and those overweight ($p < 0.0001$) were more likely to develop prediabetes, and children with obesity were more likely to develop T2D ($p < 0.0001$). Children aged 12–19 were more likely to develop prediabetes ($p < 0.0001$) and T2D ($p < 0.0001$) compared to younger children. Publicly insured children were more likely to develop T2D ($p = 0.003$). Black and Asian children were at higher risk than White individuals of developing both prediabetes ($p < 0.0001$) and T2D ($p = 0.019$ and $p = 0.02$, respectively). COVID-19 infection was not a meaningful risk factor for prediabetes or T2D.

Conclusion: Risk factors for prediabetes and T2D in children remained the same during the pandemic as prior: adolescents, overweight/obese patients, publicly insured individuals and non-White individuals.

1 | Introduction

Prediabetes and type 2 diabetes (T2D) are important causes of morbidity and mortality in the US adults, increasingly originating in childhood [1, 2]. Along with a rise in pediatric obesity, the incidence of prediabetes and T2D in children rose during the early COVID-19 pandemic [3–7]. Although obesity status, age and race are important known risk factors for prediabetes and T2D [1, 2, 7–11], it is not known if pandemic cases had the same risks. Thus, we evaluated patient characteristics associated with incident cases of prediabetes and T2D in our large integrated

care system from 2020 to 2023 to determine if risk factors changed during the pandemic.

2 | Methods

2.1 | Study Cohort

Data were extracted from the electronic health records (EHR) of children ages 0–19 years with encounters at Kaiser Permanente Mid-Atlantic States (KPMAS), a large integrated

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health system, from 2020 to 2023. The study population included patients with at least 4 months of continuous health plan membership (allowing for a gap of up to 3 months) and excluded those with prior type 1 diabetes (T1D) or T2D diagnoses.

2.2 | Outcome Variables

Incident cases of T2D (ICD-9 code 250 or ICD-10 code E11) or prediabetes (ICD-10 codes R73.03 [prediabetes] or R73.09 [abnormal HbA1c]) within the study cohort were identified. We only captured incident cases within our study period for those patients who met study population criteria (age, membership and no previous diagnosis). For patients diagnosed with T2D, we captured their initial diagnosis. For patients with prediabetes, we only captured their first prediabetes diagnosis, though they remained eligible to develop an incident diagnosis of T2D.

2.3 | Predictor Variables

Associations of each outcome variable with predictor variables of age, race, gender, ethnicity, socioeconomic status, body mass index (BMI) and documented COVID-19 infection were explored. For patients diagnosed with prediabetes or T2D, age was defined as age at diagnosis. For patients without either diagnosis, age was defined as the age at the time of first encounter during the study period. BMI was defined as the highest recorded BMI in a patient's EHR during the study period. Normal BMI status included those in the 5th–84th percentile; overweight BMI status included those in the 85th–94th percentile; obese BMI status included those at or above the 95th percentile. Socioeconomic status was determined by the patient's insurance type (public versus commercial insurance) and Social Vulnerability Index (SVI), which measures the presence of community-level social risk factors that may negatively affect the community's ability to respond to stressors or disasters [12].

2.4 | Statistical Analysis

Separate analyses were conducted to compare incident cases of prediabetes and incident cases of T2D each with the nondiabetic control group. We conducted initial chi-square analyses between each predictor variable and the outcome variables of prediabetes and T2D. Predictor variables that were significantly associated with the outcomes were retained for multivariable logistic regression analyses to identify unique predictors of prediabetes and T2D.

Results were reported with odds ratios and 95% confidence intervals. p values less than 0.05 were considered statistically significant. Chi-square analyses were performed with SAS Enterprise Guide 8.3 [13]. Logistic regression analyses were performed using SAS 9.4 [14], and forest plots were generated using R 4.4.0 [15].

The KPMAS Institutional Review Board approved this study.

3 | Results

There were 3851 prediabetes and 136 T2D incident cases in our population of 212648 children. The sample was evenly distributed by gender, had representation across the paediatric age groups and race groups, with individuals identifying as Black as the largest subgroup. Within our cohort, 19% were Hispanic and 39% were publicly insured (Table 1). Median health plan membership during the study period was 1095 days for each cohort group (prediabetes, T2D and nondiabetic control group). Thirty-eight individuals were excluded from multivariable analyses due to missing data.

We first conducted bivariate analyses to determine which predictor variables of interest to include in multivariable logistic regression analyses. For either prediabetes or T2D, we identified age, race, gender, ethnicity, BMI, COVID-19 infection, insurance type and SVI as potential risk factors (Table S1). These variables were then further investigated using multivariable analyses to determine whether they were associated with a higher risk of developing prediabetes or T2D.

Using logistic regression analyses, the odds of developing prediabetes were significantly higher among children with obesity (OR = 21.6, 95% CI: 19.0, 24.5; $p < 0.0001$) and those overweight (OR = 2.98, 95% CI: 2.5, 3.5; $p < 0.0001$) compared to those with normal weight. Children ages 12–15 (OR = 2.2, 95% CI: 2.1, 2.4; $p < 0.0001$) or 16–19 (OR = 2.1, 95% CI: 1.9, 2.3; $p < 0.0001$) had significantly higher odds of prediabetes than school-age children. Black children (OR = 4.1, 95% CI: 3.5, 4.7; $p < 0.0001$) and Asian children (OR = 3.1, 95% CI: 2.6, 3.7; $p < 0.0001$) had significantly higher odds of developing prediabetes as compared to White children (Figure 1A,C). We found a statistically significant, but weak, association between the odds of developing prediabetes and COVID-19 diagnosis (OR = 1.17, 95% CI: 1.08, 1.26; $p < 0.0001$).

The odds of developing T2D were significantly higher among children with obesity (OR = 30.6, 95% CI: 14.9, 62.9; $p < 0.0001$) compared to children with normal weight; among children ages 12–15 (OR = 6.1, 95% CI: 3.7, 10.0; $p < 0.0001$) or 16–19 years (OR = 6.4, 95% CI: 3.8, 10.8; $p < 0.0001$) as compared to school-age children; among Black children (OR = 2.3, 95% CI: 1.1, 4.5; $p = 0.019$) and Asian children (OR = 2.6, 95% CI: 1.2, 5.8; $p = 0.02$) as compared to White children; among publicly insured children (OR = 1.7, 95% CI: 1.2, 2.4; $p = 0.003$) as compared to commercially insured; and among females (OR = 1.5, 95% CI: 1.1, 2.2; $p = 0.017$) as compared to males (Figure 1B,D). We did not find any significant difference in the odds of developing T2D associated with COVID-19 infection (OR = 1.0, 95% CI: 0.7, 1.5; $p = 0.9$).

4 | Discussion

Our study found that risk factors for prediabetes and T2D in children remained the same during the pandemic: adolescents, obese or overweight patients, publicly insured individuals and non-White individuals. We also found females to be at greater risk for T2D than males. Considering that previous studies found a surge in cases during the pandemic, our finding that

TABLE 1 | Characteristics of the final study population after exclusions.

N = 212 648		Total n (%)	Prediabetic n (%)	Type 2 diabetic n (%)	Nondiabetic and nonprediabetic n (%)
Race	Black	80 087 (37.7%)	2294 (59.6%)	74 (54.4%)	77 746 (37.3%)
	White	41 948 (19.7%)	212 (5.5%)	10 (7.4%)	41 731 (20.0%)
	Asian	29 114 (13.7%)	418 (10.9%)	17 (12.5%)	28 686 (13.7%)
	Other	14 424 (6.8%)	161 (4.2%)	5 (3.7%)	14 260 (6.8%)
	Unknown	47 075 (22.1%)	766 (19.9%)	30 (22.1%)	46 293 (22.2%)
Ethnicity	Hispanic	39 184 (18.4%)	776 (20.2%)	25 (18.4%)	38 394 (18.4%)
Gender	Male	107 812 (50.7%)	1995 (51.8%)	55 (40.4%)	105 778 (50.7%)
	Female	104 836 (49.3%)	1856 (48.2%)	81 (59.6%)	102 938 (49.3%)
Age	0–4	72 742 (34.2%)	41 (1.1%)	4 (2.9%)	72 697 (34.8%)
	5–11	68 078 (32.0%)	1315 (34.2%)	21 (15.4%)	66 750 (32.0%)
	12–15	40 891 (19.2%)	1577 (41.0%)	67 (49.23%)	39 278 (18.8%)
	16–19	30 937 (14.6%)	918 (23.8%)	44 (32.4%)	29 991 (14.4%)
BMI status	Normal	84 355 (39.7%)	271 (7.0%)	8 (5.9%)	84 076 (40.3%)
	Overweight	31 728 (14.9%)	331 (8.6%)	5 (3.7%)	31 394 (15.0%)
	Obese	42 529 (20.0%)	3060 (79.5%)	117 (86.0%)	39 403 (18.9%)
COVID-19 infection during study period	Yes	43 248 (20.3%)	1014 (26.3%)	32 (23.5%)	42 195 (20.2%)
Insurance type	Commercial	130 158 (61.2%)	2289 (59.4%)	68 (50.0%)	127 829 (61.3%)
	Public	82 489 (38.8%)	1562 (40.6%)	68 (50.0%)	80 886 (38.8%)
Social Vulnerability Index (least to most vulnerable)	25% quartile	70 212 (33.0%)	963 (25.0%)	34 (25.0%)	69 224 (33.2%)
	50%	67 477 (31.7%)	1209 (31.4%)	39 (28.7%)	66 242 (31.7%)
	75%	53 944 (25.4%)	1166 (30.3%)	42 (30.9%)	52 759 (25.3%)
	100%	20 978 (9.9%)	511 (13.3%)	21 (15.4%)	20 456 (9.8%)

Note: Combined *n* for each variable may not sum to the total due to item missingness. The total *n* may not sum to the combined *n* for prediabetic, type 2 diabetic and nondiabetic and nonprediabetic columns as prediabetic and type 2 diabetic totals are not mutually exclusive.

risk factors remained the same may suggest that pre-existing vulnerable populations only grew more vulnerable during this time [3, 6]. It is possible that an unmeasured variable or background conditions contributed to the increase in T2D and prediabetes cases. However, our results reinforce the importance of addressing known risk factors, as these risks could magnify in another pandemic, climate or environmental disaster or if sedentary following injury. Steps could be taken to mitigate the impact of these circumstances for especially vulnerable subgroups.

The American Diabetes Association and the International Society for Paediatric and Adolescent Diabetes recommend screening for prediabetes and T2D in high-risk asymptomatic children, and in adolescents after the onset of puberty or at 10 years of age, whichever occurs first [2, 16, 17]. There is no consensus on optimal screening for prediabetes and T2D in lower-risk children, and insufficient evidence of benefits or harms of screening, though guidelines to assist providers in HbA1c screening for prediabetes have emerged [2, 9–11]. Decision support tools have been developed and utilised

in KPMAS since 2023 to recommend HbA1c screening for overweight or obese paediatric patients making testing more common.

Previous studies have pointed to a possible link between COVID-19 infection and diabetes [18–20], with two studies demonstrating an increase in either combined T1D/T2D risk or T2D risk among children with previous COVID-19 infection [21, 22]. Although COVID-19 infection did not emerge as a meaningful risk factor for either condition in our study, it is possible our analyses were limited by incomplete data on infection given a lack of testing for children early in the pandemic and incomplete documentation of home testing later in the pandemic. The statistically significant association we found between COVID-19 and prediabetes was small in magnitude and could be influenced by other unmeasured variables, such as pandemic-related lifestyle factors. Prospective studies are needed to determine causative effects of COVID-19 infection and other pandemic-related factors on paediatric diabetes. Among the other positive associations we did identify, we did

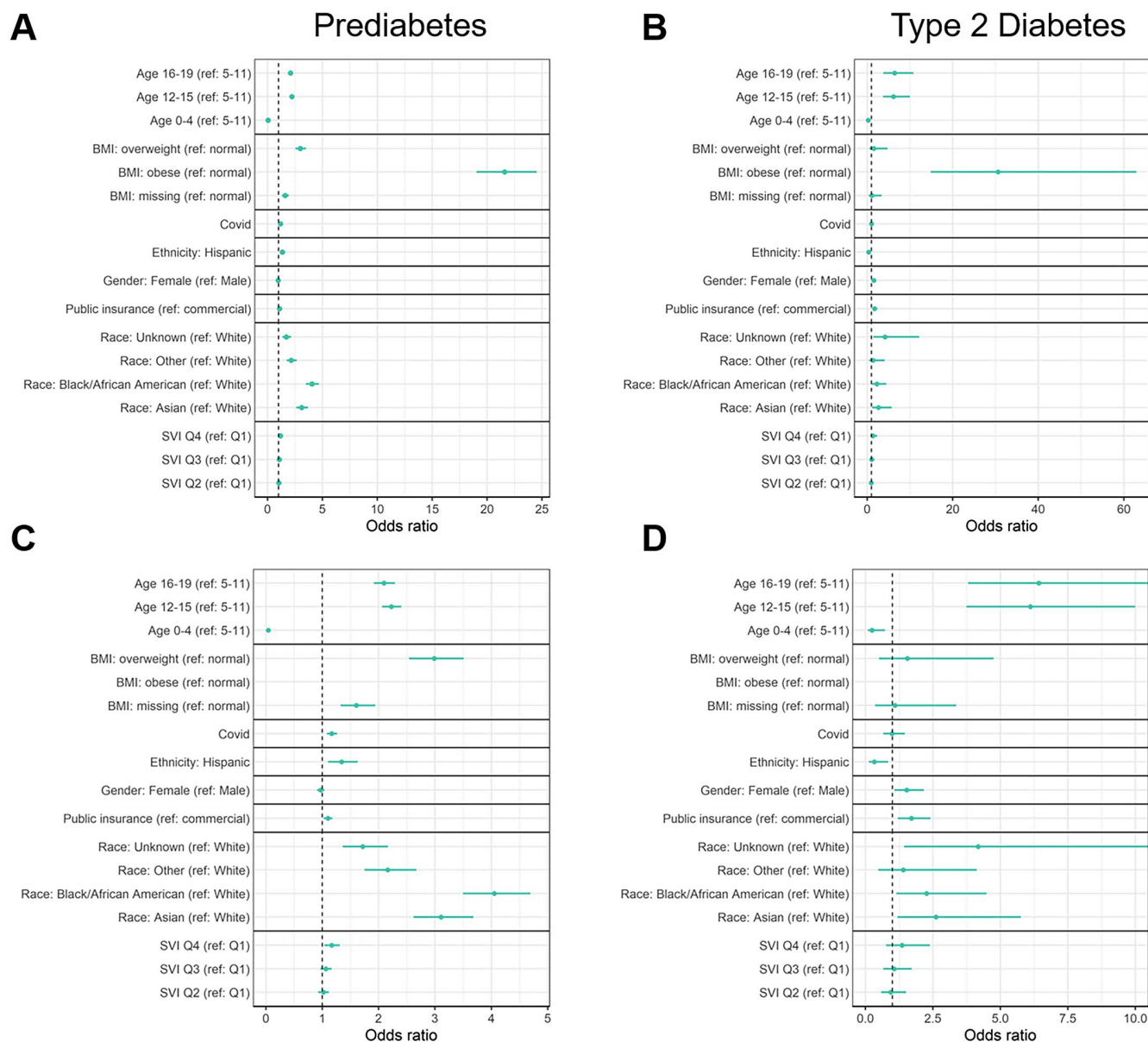


FIGURE 1 | Odds ratios of patient variables for (A and C) prediabetes and (B and D) type 2 diabetes. Panels (C) and (D) provide a magnified view of confidence intervals without the obese BMI variable.

not discover new groups at greater risk for T2D or prediabetes during the pandemic, such as normal weight individuals.

4.1 | Limitations

This study likely underestimates the incidence of T2D and prediabetes as the comparison group of nondiabetic individuals included both untested individuals and those with normal HbA1c values. We were not able to analyse progression of patients from prediabetes to T2D. Although median membership did not differ between cohort groups, it is possible that some long-term outcomes were not captured in the 3-year time frame. Additionally, our study was limited to patients within KPMAS. As such, our results reflect a population that has access to health insurance and quality health care, which may limit generalisability. We also acknowledge that a testing bias exists as only

individuals who presented for care were tested. Finally, residual confounding variables may still be present, which future work can address.

5 | Conclusion

Our study confirms that those already most vulnerable to developing prediabetes and T2D remained most vulnerable during the COVID-19 pandemic period, and no new risk factors emerged for children and teenagers. Future directions could include the development of a risk score to guide proactive HbA1c screening in paediatric patients. With regular screening, paediatric patients with prediabetes could be identified and managed before future vulnerable situations arise. Early detection and intervention could improve lifetime health status for many individuals at risk for prediabetes and T2D.

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Ethics Statement

The Kaiser Permanente Mid-Atlantic States Institutional Review Board approved this study (Study #2055381-5) with a waiver of informed consent.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Deidentified data used in this study may be available upon reasonable request to the corresponding author with appropriate data-use agreement.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Bivariate analyses comparing T2D and prediabetic groups to nondiabetic/nonprediabetic control group for variables of interest.