Changes in Type 2 diabetes trends in Children and Adolescents during the COVID-19 Pandemic

Jessica A Schmitt, MD[1], Ambika P Ashraf, MD[1], David J Becker, Ph.D[2], Bisakha Sen, Ph.D[2]

1. University of Alabama at Birmingham, Department of Pediatrics. 2. University of Alabama at Birmingham, Department of Health Policy & Organization

Corresponding Author: Bisakha Sen, Ph.D.
RPHB 330 R
1530 3rd Avenue S
Birmingham, AL 35294-0022
Tel: (205) 975-8960
Fax: (205) 934-3347
bsen@uab.edu

ORCID ID: 0000-0002-4209-4418

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Abstract:

PURPOSE: To examine whether trends in new-onset pediatric type 2 diabetes (T2D) -- inclusive of patients requiring hospitalization and patients managed outpatient -- were impacted during the COVID-19 pandemic, and to compare patient characteristics prior to and during COVID-19. METHODS: A retrospective single-center medical-record review was conducted in a hospital which cares for 90% of Alabama's pediatric T2D patients. Patients with new-onset T2D referred from March 2017-March 2021 were included. Counts of patients presenting per month ("monthly rates") were computed. Linear regression models were estimated for the full sample and stratified by Medicaid and non-Medicaid insurance status. Patient characteristics prior to versus during COVID-19 were compared. RESULTS: 642 patients presented with new-onset T2D over this period. Monthly rates were 11.1 ± 3.8 prior to COVID-19,19.3 ± 7.8 during COVID-19 (p=0.004). Monthly rates for Medicaid patients differed prior to and during COVID-19 (7.9 ± 3.4 vs 15.3 ± 6.6, p = 0.003) but not for non-Medicaid patients (3.3 ± 1.7 vs 4.0 ± 2.4, p=0.33). Regression results showed significant increases in monthly rates during COVID-19 for the full sample (β=, p<0.05) and for Medicaid enrollees (β=, p<0.05) Hospitalization-rate, severity of obesity, and hemoglobin A1c remained similar prior to and during COVID-19, though the proportion of male patients increased from 36.8% to 46.1% (p=0.021). CONCLUSIONS: A rise in new-onset T2D was observed among Alabama's youth during the COVID-19 pandemic, a burden that disproportionately affected Medicaid enrollees and males. Future research should explore the pathways through which the pandemic impacted pediatric T2D.

Keywords: COVID-19, type 2 diabetes, pediatric diabetes, Medicaid

Introduction:

Prior to the coronavirus disease 2019 (COVID-19) pandemic, the prevalence of type 2 diabetes (T2D) was increasing in the pediatric population [1]. With the onset of COVID-19 pandemic, youth saw dramatic changes in their daily routine and many families suffered loss of income. As the pandemic continued, an increase in hospitalization for new-onset T2D in youth [2] and a greater incidence in diabetic ketoacidosis at diagnosis of pediatric T2D was reported [3]. It appeared that both the incidence and severity of pediatric T2D were increasing, even in those without COVID-19 infection [3]. It is critical to understand the full impact of the COVID-19 pandemic on pediatric T2D, hence additional studies are needed. To date, the majority of literature addresses hospitalized patients with pediatric T2D, addressing only a subset of patients with new-onset T2D.

We contribute to the evidence by investigating trends in the occurrence of new-onset pediatric T2D in Alabama, both those requiring hospitalization and those managed as outpatients, and how the trends changed with the onset of the COVID-19 pandemic. Like other southeastern states, Alabama has a proportionally large non-Hispanic Black (NHB) population, higher rates of poverty, obesity, and diabetes, and generally scores low relative to other states on performance on health indicators [4-7]. To evaluate potential effects of the COVID-19 pandemic on this higher risk state's population, we used data from the Children's Hospital of Alabama (COA) where approximately 90% of the state's children and adolescents with T2D receive their medical care. We also examined differences in demographic characteristics and health indicators between patients presenting with new-onset T2D prior to and during the COVID-19 pandemic. Finally, we examined changes for Medicaid patients versus patients on other forms of insurance (hereafter "non-Medicaid") during the pandemic.

Approximately 53% of all children in Alabama are enrolled in Medicaid, which covers children in households below 146% of the Federal Poverty Level [8]; 38.1% of Medicaid enrollees are NHB, and 43.6 are non-Hispanic white (NHW) [8].

Though T2D in youth has been described as “a disease of poverty”, differences in trends in new-onset T2D between Medicaid and non-Medicaid pediatric patients is understudied in the literature [9]. Further in October 2019, Alabama Medicaid initiated a policy requiring primary care providers report a body mass index (BMI) diagnosis code on most pediatric outpatient visit claims. The policy-change, which occurred just a few months before the onset of the COVID-19 pandemic, aimed to increase timely diagnosis of obesogenic conditions for Medicaid patients and encourage appropriate referrals, and may have influenced trends in new-onset T2D for this group.

Research design and methods: We queried the electronic health record (EHR) at COA to identify patients with new-onset T2D from March 1, 2017, to March 31, 2021, including those evaluated as outpatient and those hospitalized. Diagnosis of T2D was determined by the presence of any ICD-10 code consistent with T2D (E11.x). If a patient had codes for both type 1 diabetes (E10.x) and T2D (E11.x), manual chart review was performed to determine the relevant diagnosis based upon clinical phenotype, antibody status, insulin use, and provider documentation. Information on patient demographics, vital signs, body mass index (BMI), laboratory data, whether the initial encounter was inpatient or outpatient, and insurance type was extracted. Patients admitted for inpatient stays were tested for COVID-19 using *polymerase chain reaction or* nucleic acid amplification *tests* from May 2020 onward and test results were available in the EHR. However, there was no policy of administering

COVID-19 tests for outpatients visits. BMI z-scores, also called BMI standard deviation scores, which measures relative weight for height adjusted for age and sex were constructed using World Health Organization (WHO) Child Growth Charts and WHO 2007 Reference Charts. Patients 20 years or older had a BMI z-score calculated based upon an age of 20 years. Severe obesity was defined as advised by the American Academy for Pediatrics and the American Heart Association as an absolute BMI ≥ 35 kg/m^2 or a BMI ≥ 120% of the 95^{th} percentile for age and sex [10, 11].

Analysis was conducted for the full sample and stratified by Medicaid and non-Medicaid patients. Patient characteristics were computed for the full sample, and differences between Medicaid and non-Medicaid patients were examined. These included demographic characteristics like race/ethnicity, age and self-reported sex, insurance status (for the full sample), health indicators at time of encounter like BMI-z, severe obesity, and hemoglobin A1c (HbA1c), and whether the encounter occurred in an inpatient or outpatient setting. Categorical variables were compared using chi-square tests, parametric variables were compared with two-sample t-tests and skewed variables were compared with Mann-Whitney U test.

To examine whether the number of patients per month (hereafter "monthly rates") presenting with new-onset T2D increased during COVID, monthly rates of all patients (T2D_total), Medicaid patients (T2D_Med) and non-Medicaid patients (T2D_nonMed) were computed and presented graphically. Regression models were estimated with a linear time trend a binary indicator variable (Model 1)

$$T2D_t = \beta_0 + \beta_1 Time + \beta_2 COVID\_Era_t + \varepsilon_t$$

$COVID\_Era_t$ captured the months prior versus after the onset of the COVID-19 pandemic in Alabama (0 if prior, 1 if during). April 2020 was the first full month after the March 13, 2020 declaration of a Public Health Emergency in the U.S. in response to COVID-19, and Alabama stay-at home order was initiated on April 3, 2020. As such, "prior" to COVID-19 included patients seen prior to April 2020 and "during" referred to those seen after April 2020. A second set of models (Model 2) were estimated that also incorporated a binary indicator for the Medicaid policy change (0 if prior to the policy change of October 2019, 1 if after)

$$T2D_t = \beta_0 + \beta_1 Time + \beta_2 Medicaid\_Policy_t + \beta_3 COVID\_Era_t + \varepsilon_t$$

Finally, changes in patient characteristics from prior to COVID-19 to during COVID-19 were examined for the full sample, and for Medicaid and non-Medicaid patients. Statistical significance was set at $p<0.05$. Stata (v17) was used for all analyses.

Results: Between March 2017- March 2021, 642 patients were referred for evaluation for new-onset T2D (**Table 1**). Mean age was 13.8 ± 2.5 years. The majority (n=477, 74.3%) were insured through Medicaid. In a separate examination of non-Medicaid patients not presented here, it was seen that of the non-Medicaid patients, 75.9% were privately insured, 21.4% were insured through Alabama's standalone Children's Health Insurance program, 1 individual (0.63%) was self-insured, 1 individual (0.63%) had Medicare B, and the rest were out of state or had insurance status missing.

Primary racial/ethnic categories were NHB (n=459, 71.5%), NHW (n=134 20.1%) and Hispanic (n=42, 6.5%). Median A1c was 8.1% (IQR: 6.5-11.7). Mean BMI z-score was 3.23 ± 0.69. Overall mean referral rate was 13.1 ± 6.1 patients per

month. Of the 642 patients, 278 (43.3%) had the initial encounter in an inpatient setting (**Table 1**).

The Monthly rate was 9.7 ± 5.4 in Medicaid patients compared to 3.4 ± 1.8 in non-Medicaid patients (p<0.001). Overall, Medicaid and non-Medicaid patients were similar in age, ethnic/racial demographics. Severity of T2D in Medicaid and non-Medicaid patients regarding hospitalization rates and HbA1c were similar. Mean BMI z-score was similar in Medicaid and non-Medicaid patients (3.24 ± 0.67 vs 3.22 ± 0.73, p=0.81) while severe obesity was present in 78.5% of Medicaid patients relative to 72.9% of non-Medicaid patients (p=0.15, **Table 1**).

Monthly rates are graphically presented in **Figure** 1. Monthly rate did not show any clear trend between from March 2017 until early summer of 2020. After that there was a sharp and perceptible increase in monthly rates, particularly in patients with Medicaid, a moderate decline over fall, 2020 – though still high compared with prior to COVID-19 -- and then another sharp increase in early 2021 (**Figure 1**). Due to the absence of COVID-19 test results for patients presenting for outpatient visits, we could not include that information our empirical analyses. Of the 100 patients with inpatient admissions after COVID-19 testing requirements were put in place, 93 appeared to have such testing completed. Of these, 90 (96.8%) were negative for COVID-19 by polymerase chain reaction or nucleic acid amplification testing, and three patients (3.2%) had a positive test.

Regression results with monthly rates are presented in **Table 2**. Model 1 results indicate that the time trend was essentially flat for the full sample, Medicaid, and non-Medicaid monthly rates. However, a significant increase in average monthly rates occurred during COVID compared to prior to COVID for the full sample

(β=5.53, p<0.05), that was largely driven by an increase in the Medicaid monthly rates (β=4.91, p<0.05), while non-Medicaid monthly rates showed small and statistically insignificant changes (β=0.61, p>0.05). These results on remained very similar in **Model 2,** also controlled for the Medicaid policy change binary indicator. The Medicaid policy change in itself was not significantly associated with monthly rates for the full sample, nor for Medicaid or non-Medicaid sub-groups. (**Table 2**).

Comparison of patient characteristics prior to and during COVID-19 are shown in **Table 3**. Monthly rate for all patients prior to COVID-19 was 11.1 ± 3.8 and 19.3 ± 7.8 during COVID-19 (p=0.004). Prior to COVID-19, 71.5% of all patients with new onset T2D had Medicaid insurance, during COVID-19, 79.3% of patients had Medicaid insurance (p=0.029). For Medicaid patients, monthly rates were 7.9 ± 3.4 prior to and 15.3 ± 6.6 during COVID-19 (p=0.003). There was no difference in monthly rate pre and during COVID-19 for non-Medicaid patients (3.3 ±1.7 vs 4.0 ± 2.4, p=0.33).

Prior to COVID-19, 36.8% of referred patients were male. During COVID-19, this increased to 46.1% (p=0.21). Gender breakdown prior to and during COVID-19 was similar for non-Medicaid patients, but Medicaid patients saw an increase in male patients after the pandemic (34.1% vs 46.2%, p=0.008). Ethnic and racial breakdown, age, BMI z-score, frequency of severe obesity, HbA1c, and frequency of inpatient evaluation were statistically similar prior to and during the pandemic (**Table 3**).

DISCUSSION: Existing literature shows a worrisome increase in incidence and prevalence of T2D among youth and children, disproportionately affecting low-income and ethnic minorities [1, 12, 13]. Early in the COVID-19 pandemic, hospitalization rates for new-onset pediatric T2D increased [2, 3]. This study is among the first to examine how trends of new-onset pediatric T2D of all severities, including outpatient encounters, were impacted by the COVID-19 pandemic. We found evidence that the monthly rate of pediatric patients presenting with new-onset T2D increased significantly during the COVID-19 pandemic, and that this increase was primarily driven by Medicaid patients. Further, the proportion of male Medicaid patients presenting with new-onset T2D increased significantly. Both prior to and during COVID-19, the frequency and severity of obesity in our cohort was striking and indicates that T2D disproportionately affects those with severe obesity.

Although Alabama Medicaid introduced a new policy in October 2019 aiming to increase identification of obesity and thereby increase screening for and referral for obesity-related conditions, we found no significant impact of the initial introduction of that policy with new-onset T2D rates. At the same time, the COVID-19 pandemic started within 6 months of the introduction of the policy, hence there may be an issue of collinearity that prevents detecting whether the policy by itself started having an impact a few months after its initial introduction.

Interestingly, while the absolute rate of hospitalizations for T2D in pediatrics increased during COVID-19 in both our and others [2, 3] cohorts, we did not find evidence that the frequency of hospitalization as a *proportion* of total cases for new onset T2D was significantly higher during the COVID-19 pandemic. Additionally, while rate of weight gain in youth during COVID-19 has been increasing [14, 15], we found that mean BMI z-score and frequency of severe obesity was similar in patients

presenting with new onset T2D prior to and during the COVID-19 pandemic. COVID-19 restrictions significantly changed activity and sedentary behaviors in youth during spring 2020 [16], and further work is needed to determine if these short-term changes have contributed to the rise in T2D. Our findings of the increased share of male patients, especially Medicaid male patients, during the COVID-19 pandemic is congruent with findings that adolescent males experienced greater weight gain and spent more time in sedentary activities than adolescent females during the pandemic [15]. Further research is called for to understand gender differences in risk factors for obesity-related health conditions during the pandemic.

Strengths of our study include data from a free-standing children's hospital that treats the majority of pediatric T2D patients in the state, permitting insights into the overall state and subgroup-specific trends. In contrast, prior research on T2D during COVID-19 have the limitation of small sample size and focus on inpatient hospitalizations only [2, 3]. Further, while racial and ethnic variations in incidence of T2D are well-documented [1, 13], ours is one of the first studies to examine variations between Medicaid and non-Medicaid insurance status. Pediatric T2D has been described as "a disease of poverty" [9] and Medicaid enrollment is indicative of low family-income. The disproportionate increase in T2D among Medicaid enrollees during COVID-19 suggest the pandemic further exacerbated risk factors that were already linked to poverty. Notably, there were similar proportions of non-Hispanic Black patients in the Medicaid (71.8%) and non-Medicaid groups (70.48%), thus indicating that the higher burden of T2D among minority race/ethnicity persists across income levels. Similarly, with a mean BMI z-score of 3.23 ± 0.69 and severe obesity affecting 77.1% of patients, our data is strong evidence supporting the link between severe pediatric obesity and pediatric T2D.

Our study is limited by the retrospective, observational design which does not permit causal inferences about the effect of COVID-19 on T2D. While we have data on COVID-19 infection status for hospitalized patients after May 2020, COVID-19 screening was not standard for patients evaluated in the outpatient setting. For the 93 patients with inpatient admissions for whom test results were available, only 3 had a positive COVID-19 diagnosis. However, COVID-19 tests were not required for outpatient visits, and we do not have access to COVID-19 testing outside our hospital system, hence we can only conclude that detectable COVID-19 infection was uncommon (3.2%) in our inpatient cohort. Lack of information on concurrent COVID-19 infection among those presenting for outpatient visits, or incidence of prior COVID-19 infections among all patients, is a limitation of our study. Therefore, we are unable to distinguish between the role played by direct effects on glycemia from prior COVID-19 infection and indirect effects due to changes in health behaviors after stay-at-home orders in increasing new onset T2D. We also lacked information on changes in other healthcare use, including delayed or foregone preventive care, prior to T2D diagnosis. It is unclear whether increases in T2D among Medicaid enrollees reflected the disproportionate impacts of the pandemic on low-income families. It is also possible that, increases in the Medicaid population relative to the non-Medicaid population were partly due to children previously with private insurance changing to Medicaid due to caregiver job-loss during the pandemic. It is also possible that, because of the relatively small sample of non-Medicaid patients with T2D throughout the study period, our analyses lacked statistical power to detect differences for that subgroup. Finally, the study is from one state which limits generalizability. However, as Alabama shares several socio-demographic, health

and economic characteristics with other Deep South states, these findings may be especially pertinent for those states [4, 5].

In conclusion, our findings highlight that pediatric T2D markedly increased during the COVID-19 pandemic, primarily among low-income, males, patients insured by Medicaid, and those with severe obesity and that this increase has sustained through March 2021. It is imperative to further explore the complexities of interactions between socio-economic status and lifestyle disruptions due to the COVID-19 pandemic as well as direct effects of COVID-19 glycemic status, to understand why Medicaid enrolled children faced a higher risk of new-onset T2D during this period.

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Data Availability: Data analyzed during the current study are not publicly available since it includes protected health information (PHI), but will be made available from the corresponding author on reasonable request and approval from the UAB IRB.

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Figure Legends:

Figure 1: Observed values of monthly rate in all patients, Medicaid patients, and non-Medicaid patients.

TABLES:

Table 1: Socio-Demographic and Clinical Characteristics for Full Sample & By Insurance Status

	Total n=642	**Medicaid** n=477	**Non-Medicaid** n=165	P-value
Monthly rate mean (SD)	13.1 (6.1)	9.7 (5.4)	3.4 (1.8)	<0.001
Medicaid-insured n (%)	477 (74.3)			
Sex: n (%): Male	258 (40.2)	185 (38.8)	73 (44.2)	0.22
Race: n (%) NHW NHB Hispanic Other	 134 (20.1) 459 (71.5) 42 (6.5) 7 (1.1)	 96 (20.1) 342 (71.7) 35 (7.3) 4 (0.8)	 38 (23.0) 117 (70.9) 7 (4.2) 3 (1.8)	0.34
Age in years mean (SD)	13.8 (2.5)	13.7 (2.4)	14.1 (2.9)	0.117
HbA1c Median (IQR)	8.1 (6.5-11.7) n=629	8.0 (6.5-11.6) n=472	8.5 (6.6-12.1) n=157	0.34
BMI z-score mean (SD)	3.23 (0.69) n=607	3.24 (0.67) n=456	3.22 (0.73) n=0.73	0.81
Severe obesity: n (%)	474 (77.1) n=615	361 (78.5) n=460	113 (72.9) n=155	0.15
Inpatient Evaluations: n (%)	278 (43.3)	210 (44.0)	68 (41.2)	0.53

SD = standard deviation; NHW = non-Hispanic white; NHB= non-Hispanic Black; SD = standard deviation; IQR=inner quartile range; HbA1c=hemoglobin A1c (in %, to convert to mmol/mol subtract 2.15 and multiply by 10.929.

Table 2: Results from Least Square Regressions of Monthly COVID Cases

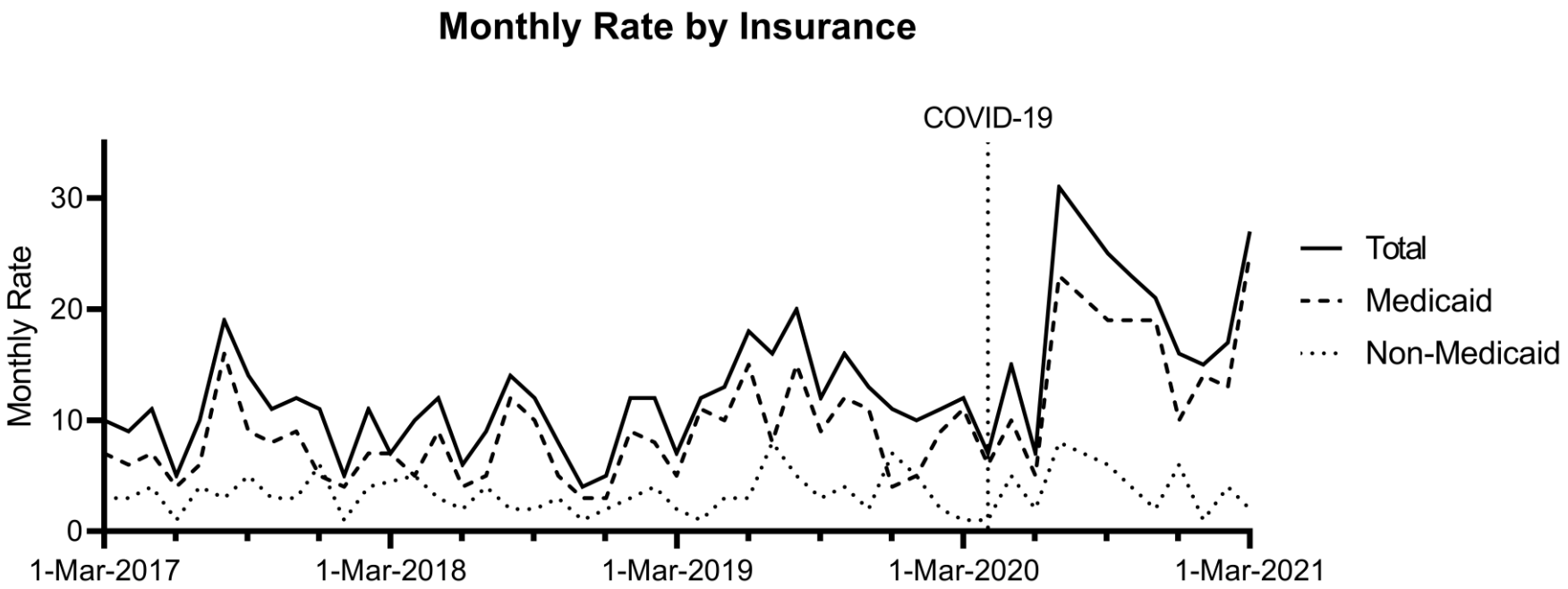
	Full Sample β [95% C.I.]	Medicaid β [95% C.I.]	Non-Medicaid β [95% C.I.]
Model 1:			
Time in months	0.11 [-0.04 to 0.26]	0.10 [-0.03 to 0.23]	0.01 [-0.05 to 0.07]
COVID Era	5.53** [0.55 to 10.51]	4.91** [0.60 to 9.23]	0.61 [-1.32 to 2.54]
Intercept	8.97** [5.66 to 12.28]	5.98** [3.11 to 8.85]	2.99** [1.70 to 4.27]
R^2	0.37	0.39	0.04
Model F	13.59	14.47	0.41
Model 2:			
Time in months	0.14 [-0.06 to 0.33]	0.14 [-0.03 to 0.31]	0.0001 [-0.08 to 0.08]
Medicaid policy change	-1.26 [-7.04 to 4.53]	-1.64 [-6.64 to 3.36]	0.39 [-1.86 to 2.63]
Post-COVID	5.92** [0.58 to 11.27]	5.43** [0.81 to 10.05]	0.49 [-1.58 to 2.57]
Intercept	8.67** [5.03 to 12.29]	5.58** [2.45 to 8.72]	3.09** [1.67 to 4.49]
R^2	0.37	0.40	0.04
Model F	8.97	9.81	0.60
** p<0.05			

Table 3: Differences in Socio-Demographic and Clinical Characteristics between Patients in the Pre-COVID-19 Pandemic and during COVID-19 Pandemic

	All Patients			Medicaid Patients			Non-Medicaid Patients		
	Pre-COVID n=410	During COVID n=232	P-value	Pre-COVID n=293	During COVID n=184	P-value	Pre COVID n=117	During COVID n=48	P-value
Monthly rate mean (SD)	11.1 (3.8)	19.3 (7.8)	0.004	7.9 (3.4)	15.3 (6.6)	0.003	3.3 (1.7)	4.0 (2.4)	0.33
Medicaid Insurance	293 (71.5)	184 (79.3)	0.029	--	--	--	--	--	--
Sex: n (%): Male	151 (36.8)	107 (46.1)	0.021	100 (34.1)	85 (46.2)	0.008	51 (43.6)	22 (45.8)	0.79
Race: n (%) NHW NHB Hispanic Other	90 (22.0) 287 (70.0) 29 (7.1) 4 (1.0)	44 (19.0) 172 (74.1) 13 (5.6) 3 (1.3)	0.66	60 (20.5) 207 (70.6) 23 (7.8) 3 (1.0)	36 (19.6) 135 (73.4) 12 (6.5) 1 (0.5)	0.86	30 (25.6) 80 (68.4) 6 (5.1) 1 (0.9)	8 (16.7) 37 (77.1) 1 (2.1) 2 (4.2)	0.23
Age in years mean (SD)	13.7 (2.5)	13.7 (2.6)	0.89	13.7 (2.4)	13.6 (2.4)	0.85	14.0 (2.8)	14.2 (3.0)	0.77
HbA1c Median (IQR)	7.8 (6.4-11.5) n=400	8.6 (6.6-12.1) n=229	0.082	7.5 (6.4-11.3) n=289	8.3 (6.6-12.1) n=183	0.070	8.1 (6.6-11.8) n=111	9.0 (6.7-12.8) n=46	0.57
BMI z-score mean (SD)	3.23 (0.70)	3.24 (0.67)	0.92	3.24 (0.68) n=273	3.24 (0.68) n=183	0.93	3.21 (0.75) n=105	3.25 (0.68) n=46	0.76
Severe obesity: n (%)	296 (76.9) n=385	178 (77.4) n=230	0.88	217 (78.6) N=276	144 (78.3)	0.93	79 (72.4) n=109	34 (70.8) n=46	0.85
Inpatient Evaluations: n (%)	173 (42.2%)	105 (45.3%)	0.45	129 (44.0)	81 (44.0)	0.999	44 (37.6)	24 (50.0)	0.14

SD = standard deviation; NHW = non-Hispanic white; NHB= non-Hispanic Black; SD = standard deviation; IQR=inner quartile range; HbA1c=hemoglobin A1c (in %, to convert to mmol/mol subtract 2.15 and multiply by 10.929.

Figure 1


Monthly Rate by Insurance
COVID-19
Monthly Rate
30
20
10
0
1-Mar-2017
1-Mar-2018
1-Mar-2019
1-Mar-2020
1-Mar-2021
Total
Medicaid
Non-Medicaid