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Changes in obesity and diabetes severity during the COVID-19 pandemic at Virginia Commonwealth University Health System

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Abstract

Introduction: The COVID-19 pandemic significantly changed the lives of millions of people in the USA, preventing them from continuing their regular lifestyles. This study examined the manifestation of "Covibesity" in the patient population of the Virginia Commonwealth University (VCU) Health System and explored the effects of the distraction caused by the pandemic in the management of diabetes disease. *Methods:* This project analyzed body mass index (BMI) rates of the general adult patient population at the VCU Health System during the COVID-19 pandemic compared to prior years. The project also investigated the changes in the severity of diabetes cases treated at the VCU Health System by comparing HbA1c laboratory results and the number of diabetes-related emergency department (ED) visits before and during the pandemic. The results were stratified by age, gender, and race to examine subpopulations. *Results:* The mean BMI for the general patient population increased from 2018 to 2019 but decreased in 2020. The mean HbA1c measurements for the diabetic patient population increased from 2018 to 2020, while the number of ED visits declined in 2020 for the same population. When stratified by race, the trends in the outcomes largely reflected those of the overall mean. The African American population had a higher mean BMI, HbA1c, and number of ED visits than other races, but showed the same temporal behavior to the overall mean.

Introduction

Obesity is a global pandemic that negatively affects multiple aspects of individuals' well-being, and is a known risk factor for diabetes and other diseases. According to the National Center for Health Statistics, 42.5% of the US population aged 20 and older were classified as obese in 2018 [1,2]. A few studies in different countries have documented an increase in body mass index (BMI) after the lockdown caused by the COVID-19 pandemic [3,4] including in the USA, where 42% of adults surveyed reported an undesired increase in weight [5]. Multiple studies found that the pandemic has led to behavioral changes that increased the tendency of individuals to gain weight, including changes in nutritional choices, financial burdens, psychological alterations, and physical activity patterns [6,7]. Additionally, food companies have initiated innovative marketing techniques since the start of the pandemic, which added to increased unhealthy food and alcohol consumption [8].

Obesity has a strong negative effect on diabetes mellitus (DM) prognosis. Obesity is the most prominent risk factor for insulin resistance in the USA, which is the main reason for Type 2 DM [9]. More than 90% of diabetic patients are classified as having Type 2 DM. Though obesity is less of a risk factor for Type 1 diabetes, it plays an important role in the management of Type 1 DM as well. About 11% of the US population suffers from Type 1 or Type 2 diabetes [10], and over 75% of DM patients are obese [11].

There is evidence that obesity reduces the glycemic control of diabetic patients in addition to increasing the severity of comorbidities [12]. A common way of evaluating diabetes disease is measuring the concentration of Hemoglobin A1c (HbA1c), which depends on both the concentration of glucose in the blood and the life span of red blood cells. Since the average lifespan of red blood cells is about 120 days, HbA1c reflects the integrated glucose concentration over 8–12 weeks prior to the test. This offers the advantage of eliminating day-to-day fluctuations that occur in blood glucose concentrations [13]. In addition, HbA1c blood samples can be taken at any time of the day without patient preparations [14]. The HbA1c concentration is frequently

used to monitor the glycemic status in both Type 1 and Type 2 diabetes patients over time. This measurement helps to indicate the degree of glycemic control, response to treatment, and the risk of development of diabetes-related complications. A higher level of HbA1c is strongly suggestive of poorly controlled diabetes [15,16]. An HbA1c level of at least 6.5% would be diagnostic of diabetes if confirmed by an elevated blood glucose level [17].

Uncontrolled glucose levels were found to affect the morbidity and mortality of diabetic patients infected with COVID-19. Diabetic patients infected with COVID-19 are twice more likely to develop severe COVID-19 disease with twice the risk of mortality. Therefore, a large portion of diabetics presents with COVID-19 infection present to the ER with severe respiratory symptoms and are admitted to the hospital [18]. A study by Ghosal et al. demonstrated that poor glycemic control increased the risk of mortality in diabetic patients with COVID-19. The authors also found that the duration of lockdown was directly proportional to the deterioration of glycemic control and diabetes-related complications [19].

About 30% of the patient population of the VCU Health System are African American. African Americans are documented to experience more detrimental effects related to diabetes. The National Center for Health Statistics reports that 24.9% of African American diabetic patients have poor glycemic control, compared to only 8.8% of non-Hispanic White diabetic patients. African Americans are 2.1 times more likely to die from diabetes [20] and 1.7 times more likely to be hospitalized as a result of diabetes compared to non-Hispanic Whites [21]. This difference in complication rates can be attributed to many factors, such as the disproportionate socioeconomic status of African Americans, compared to non-Hispanic Whites. Additionally, blood glucose monitoring rates are significantly lower for African Americans than those for non-Hispanic Whites [22], further increasing the risk of uncontrolled diabetes. Minority populations such as African Americans constitute 20% of the rural population, where there is limited access to primary healthcare and lower screening rates of chronic diseases [23]. Death rates of diabetes in African Americans are higher in rural areas of the USA than in urban areas as well as those in the rural White population [24–26].

The aims of this research project were to: (a) evaluate and compare BMI levels before the COVID-19 pandemic (2018–2019) and during the COVID-19 pandemic (2020) of all adult patients seen at VCU Health System, as well as (b) investigate the changes in the severity of diabetes cases treated at the VCU Health System by comparing HbA1c laboratory results and the number of diabetes-related emergency department (ED) visits before and during the pandemic. Considering the large portion of minority patients among VCU Health System's population, it was important to stratify analysis by subpopulations. It was hypothesized that BMI levels would increase during the COVID-19 pandemic compared to previous years due to disruption of lifestyle in Virginia. Additionally, it was hypothesized that the severity of diabetes cases would increase as measured by higher HbA1c values and a larger number of diabetes-related ED visits.

Methods

Data Source

The study used de-identified retrospective data from electronic health records (EHRs) at the VCU Health System, which included encounters between January 2018 and December 2020. The data were provided by the Biomedical Informatics Core at the VCU Wright Center for Clinical and Translational Research. Since the requested data was completely de-identified, this project was not considered human subject research, and therefore did not require review from the VCU Institutional Review Board. There were two datasets created. The first dataset included aggregated monthly mean BMI measurements for all adult patients who visited any VCU Health System locations in the study period. BMI is a calculated variable in VCU Health System's EHR system without any validation, which sometimes results in errors, producing unreasonable outlier values for BMI. To reduce these errors, we removed BMI values from the dataset that were less than 10 (BMI value for an average height 70 pound man), or more than 70 (BMI value for an average height 500 pound man). If a patient had multiple visits in a month with BMI measurements, the mean of the BMI values was calculated for the patient for that month. The dataset included gender, age (18–19, 20–39, 40–59, >60), race, and ethnicity of the patients. We categorized patients as overweight if their monthly mean BMI index was larger than 25. This dataset was referred to as the *BMI cohort* in the study. The second dataset included aggregated monthly mean HbA1c measurements for all adult patients who had Type 1 or Type 2 diabetes diagnoses and visited any VCU Health System locations in the study period. HbA1c lab values are clinically validated in the EHR system, therefore we did not remove any of these values due to being outliers. If a patient had multiple visits in a month with HbA1c measurements, the mean of the HbA1c values was calculated for the patient for that month. Only visits with HbA1c measurements were included in this cohort. The dataset also included the number of ED visits for the month, as well as gender, age (18–19, 20–39, 40–59, >60), race, and ethnicity of the patients. We categorized patients as being in a poor glycemic state if their monthly mean HbA1c lab value was larger than 6.4. This dataset is referred to as the *Diabetes cohort* in the study. We excluded the demographic variable *ethnicity* from reporting as each cohort had less than 2% Hispanic population and the results for those Hispanic patients were not significantly different from non-Hispanics.

Data Analysis

All data for the BMI and diabetes cohorts were summarized using proportions for categorical variables, as well as mean and standard deviation for numeric variables. For each outcome (BMI, HbA1c and number of ED visits), we stratified the results by gender, age, race, and ethnicity to identify trends in subpopulations. Since there was repetition in observations per patient, we chose to conduct a mixed model analysis using the patient as the random effect and only a random intercept. For each of the three outcomes, we constructed four models. First, we constructed a simple linear model to assess temporal association with the outcome. Our second model was a mixed model, with a *patient* random effect and *year* as a continuous fixed effect to assess whether the temporal association with the outcome was clustered among individuals. Similarly to model 2, our third mixed model used *year* as a categorical-fixed effect to assess changes in trends for year 2020, the COVID-19 inflection point. Our last model included an interaction between *year* and *race* to assess the temporal association in subpopulations. The original race variable was consolidated to African American, White, and Other; where Asian, American Indian, and multi-racial were grouped with Other since they were a small percentage of each cohort. When *year* was modeled as categorical measure (as done in models 3 and 4), we looked at pairwise differences for all factors in the mixed model, computed

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Table 1. *Body Mass Index (BMI) cohort summary table*

		Total			Percentage		
Variable	Group	2018	2019	2020	2018	2019	2020
Total		69,604	89,718	98,475	46.5%	53.4%	63.4%
Age	18–19	1724	2272	1575	2.5%	2.5%	1.6%
Age	20–39	16,451	21,288	24,177	23.6%	23.7%	24.6%
Age	40–59	25,030	31,032	33,181	36.0%	34.6%	33.7%
Age	>60	26,264	34,977	39,542	37.7%	39.0%	40.2%
Age	Missing	135	149	0	0.2%	0.2%	0%
Gender	Female	43,057	54,848	60,034	61.9%	61.1%	61.0%
Gender	Male	26,546	34,869	38,440	38.1%	38.9%	39.0%
Race	American Indian	70	91	103	0.1%	0.1%	0.1%
Race	Asian	744	1022	1090	1.1%	1.1%	1.1%
Race	African American	30,099	37,024	41,024	43.2%	41.3%	41.7%
Race	Multiple	114	148	167	0.2%	0.2%	0.2%
Race	Other/unknown	2811	4584	5041	4.0%	5.1%	5.1%
Race	White	35,766	46,849	51,050	51.4%	52.2%	51.8%
Overweight	Yes (BMI ≥ 25)	51,250	66,019	72,402	73.6%	73.6%	73.5%
Overweight	No (BMI < 25)	18,354	23,699	26,073	26.4%	26.4%	26.5%
			Mean			**Standard deviation**	
BMI	American Indian	30.52	30.99	30.66	7.63	7.40	6.94
BMI	Asian	25.64	25.71	25.69	4.93	5.03	4.98
BMI	African American	31.97	32.03	31.98	8.21	8.28	8.36
BMI	Multiple	29.63	29.62	29.54	8.76	8.90	8.40
BMI	Other/unknown	29.11	29.32	29.31	6.58	6.80	6.75
BMI	White	29.49	29.53	29.51	7.19	7.20	7.24
BMI	Overall	30.56	30.57	30.54	7.75	7.78	7.82

p-values and confidence intervals based on the t-distribution using degrees of freedom based on a Satterthwaite approximation. The reference values for the categorical variables were the *year* 2020 and Other *race*. The contrasts in means were plotted, highlighting groups that had a significant difference in means between each year. For the *BMI* and *HbA1c* outcomes, we used a standard mixed model since the outcome is continuous and normally distributed. The *Number of ER Visits* followed a Poisson process, so we used a generalized mixed model for this outcome. To improve model convergence, the *race* variable was limited to just African Americans in the generalized mixed model. From the regular mixed models, we report the fixed and random effects with a 95% confidence interval from the profile likelihood. From the generalized mixed models, we report the fixed effect, random intercept, and p-values for significance. We also report the intraclass correlation to assess how similar values are within clusters. All analysis was done in R 4.0 using the lme4 package for mixed models.

Dichotomous outcomes for *overweight* and *poor glycemic state* were added to our analysis. The outcomes followed the overweight threshold (BMI ≥ 25) and high HbA1c threshold (HbA1c ≥ 6.4). Additionally, a generalized estimating equation model was used to determine the clustered association of these outcomes, and the change in rate during the year of the COVID-19 pandemic, 2020. In this model, we included a knot for the year 2020, to determine if a change took place in this year compared to years prior. For our GEE analysis, we used the R package Geepack.

Results

Table 1 contains summary statistics for the BMI cohort, while Table 2 shows summary statistics for the diabetes cohort.

BMI Analysis

This analysis used the *BMI cohort* to assess trends in BMI change for the whole adult population of VCU Health System. The summary tables from the models are described in Table 3. From the simple linear model 1, there is no sign of association between time in years and BMI since the 95% CI contains 0 [−0.013 slope (−0.034, 0.009)]. However, after including a random effect for the patient (model 2), the BMI increases over time 0.0083 (95% CI 0.002, 0.0143). For model 3, considering year as a category, we see that only the year 2018 has a nonzero slope [−0.017 (95% CI: −0.029, −0.006)] compared to the reference of the year 2020 (the time of the pandemic). There is no significant change in BMI comparing 2019–2020 [0.0003 (95% CI: −0.010, 0.011)].

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Table 2. *Diabetes cohort summary table*

		Total			Percentage		
Variable	Group	2018	2019	2020	2018	2019	2020
Total		19,482	22,376	27,652	49.4%	56.8%	70.2%
Age	18–19	83	99	119	0.4%	0.4%	0.4%
Age	20–39	1551	1667	1965	8.0%	7.4%	7.1%
Age	40–59	7757	8420	9720	39.8%	37.6%	35.2%
Age	>60	10,084	12,179	15,836	51.8%	54.4%	57.3%
Age	Missing	7	11	12	0.0%	0.0%	0.0%
Gender	Female	11,096	12,544	14,966	57.0%	56.1%	54.1%
Gender	Male	8386	9832	12,686	43.0%	43.9%	45.9%
Race	American Indian	29	31	37	0.1%	0.1%	0.1%
Race	Asian	194	226	274	1.0%	1.0%	1.0%
Race	African American	10,898	12,168	14,580	55.9%	54.4%	52.7%
Race	Multiple	40	44	53	0.2%	0.2%	0.2%
Race	Other/unknown	865	1090	1647	4.4%	4.9%	6.0%
Race	White	7456	8817	11,061	38.3%	39.4%	40.0%
High HbA1c	Yes (HbA1c ≥ 6.4)	4271	5224	6752	54.2%	59.3%	63.0%
High HbA1c	No (HbA1c < 6.4)	3606	3581	3969	45.8%	40.7%	37.0%
Obese	Yes (BMI ≥ 25)	15,473	177714	20,129	87.3%	86.5%	84.9%
Obese	No (BMI < 25)	2248	2755	3589	12.7%	13.5%	15.1%
			Mean			**Standard Deviation**	
HbA1c	American Indian	7.153	7.785	7.520	1.135	1.468	1.588
HbA1c	Asian	6.773	7.380	7.308	1.361	1.668	1.673
HbA1c	African American	7.288	7.363	7.475	2.017	1.917	1.995
HbA1c	Multiple	7.178	7.152	7.279	1.681	1.444	2.498
HbA1c	Other/unknown	7.095	7.248	7.331	1.749	1.771	1.816
HbA1c	White	6.967	7.105	7.234	1.651	1.630	1.735
HbA1c	Overall	7.150	7.254	7.370	1.870	1.799	1.886
ED Visits	American Indian	0.413	0.129	0.324	0.682	0.428	0.784
ED Visits	Asian	0.211	0.248	0.266	0.490	0.626	0.689
ED Visits	African American	0.855	0.845	0.727	1.409	1.409	1.270
ED Visits	Multiple	2.000	1.977	1.321	1.812	1.759	1.300
ED Visits	Other/unknown	0.559	0.530	0.420	1.108	1.198	0.985
ED Visits	White	0.487	0.489	0.453	1.088	1.102	0.962
ED Visits	Overall	0.696	0.685	0.595	1.291	1.294	1.144

Hemoglobin A1c (HbA1c); Emergency Department (ED).

There is no substantial change in BMI from before COVID to during COVID.

When looking at race subpopulations in model 4, we notice that changes in BMI stratified by race are nonzero, meaning that change over time is statistically significant compared to the inflection point of the year 2020. Looking at the African American population, the pairwise contrast for African Americans in 2020 compared to 2019 [0.027, (95% CI: 0.011, 0.044)] and for 2020 compared to 2018 [0.049 (95% CI: 0.031, 0.067)] shows that the rate of BMI is increasing, albeit negligibly. This is different from what was shown in the summary statistics of the overall means, where the BMI in 2020 is less than in 2019. However, we do notice a larger variance in BMI measures in 2020, which could influence the result of the mixed models. The African American population has a higher BMI than other races. The comparison within the same race over time shows an increase in BMI albeit trivial before COVID to during COVID. The intraclass correlation coefficient (ICC) from the mixed models is all greater than 0.9, suggesting that the BMI within each patient cluster is similar over time. In other words, while there may be statistically significant changes in BMI over time within a cluster, these changes are trivial. BMI largely stays the same over time.

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Table 3. *Body Mass Index (BMI) models using the BMI cohort*

Model	Fixed effects	Estimates	Random effects	Estimate of SD	ICC
Model 1 (linear model)	Intercept	30.57 (30.540, 30.596)	NA	NA	NA
	Time	−0.013 (−0.034, 0.009)			
Model 2	Intercept	30.22 (30.173, 30.267)	Patient	7.380 (7.347, 7.413)	0.932
	Time	0.0083 (0.002, 0.0143)	Residual	1.999 (1.996, 2.002)	
Model 3	Intercept	30.22 (30.17, 30.26)	Patient	7.380 (7.347, 7.413)	0.932
	Yr2018	−0.0174 (−0.029, −0.006)	Residual	1.999 (1.996, 2.002)	
	Yr2019	0.0003 (−0.010, 0.011)			
Model 4	Intercept	28.53 (28.35, 28.72)	Patient	7.273 (7.241, 7.306)	0.930
	Yr2018	−0.182 (−0.235, −0.130)	Residual	1.995 (1.996, 2.002)	
	Yr2019	−0.094 (−0.139, −0.049)			
	RaceAA	3.174 (2.979, 3.369)			
	RaceWhite	0.725 (0.532, 0.917)			
	2018*AA	0.133 (0.078, 0.189)			
	2019*AA	0.067 (0.019, 0.115)			
	2018*White	0.210 (0.154, 0.265)			
	2019*White	0.129 (0.082, 0.177)			

Not Applicable (NA); Year (Yr); African American (AA); Standard Deviation (SD); Intraclass Correlation Coefficient (ICC).

Table 4. *HbA1c models using the diabetes cohort*

Model	Fixed effects	Estimates	Random effects	Estimate of SD	ICC
Model 1 (linear model)	Intercept	7.148 (30.540, 30.596)	NA	NA	NA
	Time	0.110 (−0.034, 0.009)			
Model 2	Intercept	7.132 (7.099, 7.165)	Patient	1.559 (1.537, 1.582)	0.668
	Time	0.103 (0.086, 0.119)	Residual	1.100 (1.089, 1.110)	
Model 3	Intercept	7.328 (7.30, 7.36)	Patient	1.559 (1.537, 1.582)	0.668
	Yr2018	−0.206 (−0.240, −0.173)	Residual	1.099 (1.089, 1.110)	
	Yr2019	−0.071 (−0.102, −0.039)			
Model 4	Intercept	7.28 (7.169, 7.392)	Patient	1.554 (1.532, 1.577)	0.668
	Yr2018	−0.285 (−0.409, −0.161)	Residual	1.099 (1.089, 1.110)	
	Yr2019	−0.022 (−0.139, 0.095)			
	RaceAA	0.163 (0.044, 0.283)			
	RaceWhite	−0.106 (−0.229, 0.017)			
	2018*AA	0.099 (−0.033, 0.231)			
	2019*AA	−0.069 (−0.195, 0.055)			
	2018*White	−0.058 (−0.077, 0.193)			
	2019*White	−0.031 (−0.161, 0.094)			

Not Applicable (NA); Year (Yr); African American (AA); Standard Deviation (SD); Intraclass Correlation Coefficient (ICC).

HbA1c Analysis

This analysis used the *diabetes cohort* to assess trends in glycemic state change for the diabetic adult population of VCU Health System. The result tables from the models are described in Table 4. HbA1c is positively correlated with time both in the simple linear model and the mixed model. When accounting for the random effect (model 2), the mean HbA1c increased by 0.103 (95% CI: 0.086, 0.119), which reflected what was seen in the data summary table (Table 2); an increase from 2018 to 2019 and another increase in 2020. When considering year as a factor (model 3), both 2018 [−0.206 (95% CI: −0.240, −0.173)] and 2019 [−0.075 (95% CI: −0.102, −0.039)] have nonzero slope, indicating that 2020 has a higher HbA1c than these years. Figure 1 shows the pairwise contrasts in years for HbA1c, indicating the same conclusion that 2020

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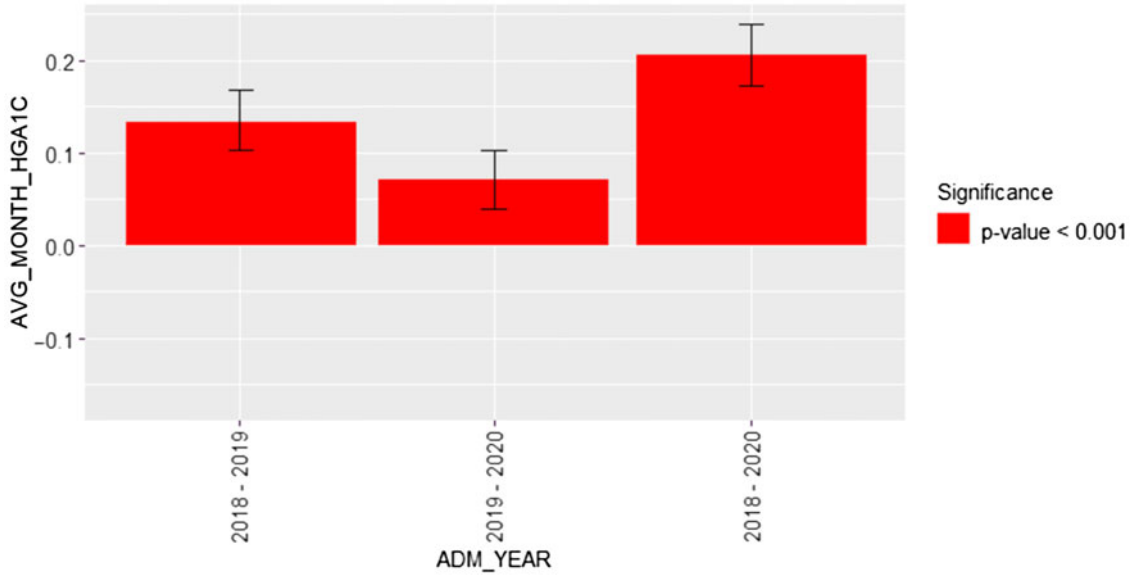

Fig. 1. Hemoglobin A1c/year contrast. Hemoglobin A1c (HGA1C); Admission (ADM).

has a higher mean HbA1c when controlling for random error in the patient. When stratifying by race, we see that this contrast for 2020 to other years for African Americans also indicates an increase in HbA1c: with 2018 [0.186 (95% CI: 0.140, 0.231)] and with 2019 [0.092 (95% CI: 0.048, 0.135)]. The ICC for the mixed models was all 0.668 meaning there was less within-cluster consistency in HbA1c measure per patient than there was with BMI. It is possible that after a high HbA1c measure at one visit, the patient was encouraged to lower their blood sugar to regulate their diabetes before a second visit, resulting in more fluctuation within a subject. Similarly to BMI, the change in HbA1c over time is largely trivial before and during the pandemic.

Number of ED Visits Analysis

This analysis used the *diabetes cohort* to assess trends in number of Emergency Department visits for the diabetic adult population of VCU Health System. The results for the number of ED visits models are described in Table 5. The number ED visits is negatively associated over time [−0.081 (p-value <0.05)] in the simple generalized linear model, which reflects the summary table (Table 2), a decreasing trend can be seen in ED visits over time from 2018 to 2020. In model 2, adding the random patient effect, the negative trend persists [−0.067 (p-value <0.05)] as the number of ED visits decreases from 2018 to 2020. As for model 3, with year as a categorical variable, both 2018 [0.13, p-value <0.05] and 2019 [0.133, p-value <0.05] show that the number of ED visits is greater before COVID than during the year 2020 during the COVID-19 pandemic. Using model 4, we looked at pairwise differences between year and race, and again see a decreasing trend in ED visits from 2018 to 2020 [2020 AA estimate – 2018 AA estimate: −0.140, p-value <0.05] and from 2019 to 2020 [2020 AA estimate – 2019 AA estimate: −0.143, p-value <0.05]. This reaffirms that the number of ED visits decreases as well in the African American population.

Generalized Estimating Equation (GEE) Analysis

Our additional models dichotomized the BMI and HbA1c variables to distinguish overweight patients using a threshold of BMI ≥ 25 and patients with poor glycemic state using a threshold of HbA1c ≥ 6.4. The output for both the *high HbA1c* and *overweight* GEE models can be seen in Table 6. Key to our assessment is the interaction between a knot of the year 2020 (the year of the pandemic) and an indicator for race, particularly African American. For the overweight model, there is no significant change in the risk of being overweight for African Americans in the pandemic year compared to prior years [−0.011, p-value 0.830]. Further, in the overweight GEE model, there is no temporal association with risk of being overweight and no change in risk for the year of the pandemic across all races. This reinforces what was seen in the generalized model, if there was a change in BMI, it was negligible and did not shift persons from a non-overweight category to an overweight category. Also within each person, BMI has very little change over time. For the high HbA1c model, there is no significant change in rate of high HbA1c compared before and during the pandemic for the African American population [0.219, p-value 0.166]. Despite a significant trend in temporal risk of high HbA1c from 2018 to 2020, the risk of high HbA1c decreases during the pandemic year in the GEE model when not stratifying for race. This result on its face conflicts with that of the generalized linear model, however our modeling of the continuous measure showed a small decimal change over time which may mean that overall, this does not shift categorizations of high HbA1c by much. Likely a person with high HbA1c will always have high HbA1c, same with those with low HbA1c.

Discussion

The respiratory disease, coronavirus 2019 (COVID-19), has had an enormous effect on global health. An overlooked outcome, however, is its indirect effects on obesity, and how that has impacted diabetes. The prevalence of obesity continues to rise worldwide, and it is often described as being an epidemic. In the USA, the African American population is especially affected by the obesity epidemic.

Our study analyzed BMI data of the general adult population between January 2018 and December 2020 at the VCU Health System, an academic safety-net healthcare institution serving a large

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Table 5. *Emergency department visit count models using the diabetes cohort*

Model	Fixed effects	Estimates (p-value)	Random effects	Estimate of SD	ICC ($\sigma^2_e = 2.36$)
Model 1 (linear model)	Intercept	−0.339 (<0.05)	NA	NA	NA
	Time	−0.081 (<0.05)			
Model 2	Intercept	−1.075 (<0.05)	Patient	1.216	0.386
	Time	−0.067 (<0.05)			
Model 3	Intercept	−1.099 (<0.05)	Patient	1.217	0.386
	Yr2018	0.129 (<0.05)			
	Yr2019	0.133 (<0.05)			
Model 4	Intercept	−1.530 (<0.05)	Patient	1.188	0.374
	Yr2018	0.086 (<0.05)			
	Yr2019	0.099 (<0.05)			
	AA	0.570 (<0.05)			
	2018*AA	0.054 (0.04)			
	2019*AA	0.05 (0.06)			

Not Applicable (NA); Year (Yr); African American (AA); Standard Deviation (SD); Intraclass Correlation Coefficient (ICC).

Table 6. *Generalized Estimating Equation models for HbA1c (diabetes cohort) and BMI (BMI cohort)*

Model	Effect	Estimates	Sandwich estimator, SE	Wald statistic	p-value
High HbA1c (≥6.4)	Inter:No	0.214	0.089	5.826	0.016
	TimeYr	0.360	0.090	16.112	0.000
	AA	0.109	0.094	1.334	0.248
	White	0.058	0.097	0.365	0.546
	Yr2020	−0.270	0.148	3.341	0.068
	AA:yr2020	0.219	0.158	1.922	0.166
	White:yr2020	0.175	0.161	1.173	0.279
	TimeYr:AA	−0.194	0.096	4.122	0.042
	TimeYr:White	−0.155	0.098	2.472	0.116
Overweight (BMI ≥ 25)	Inter:No	0.705	0.040	304.134	0.000
	TimeYr	0.047	0.033	2.052	0.152
	AA	0.633	0.044	210.624	0.000
	White	0.203	0.043	22.681	0.000
	Yr2020	−0.031	0.046	0.456	0.499
	AA:yr2020	−0.011	0.050	0.046	0.830
	White:yr2020	0.042	0.049	0.728	0.393
	timeYr:AA	−0.040	0.035	1.279	0.258
	timeYr:White	−0.054	0.034	2.516	0.113

Hemoglobin A1c (HbA1c); Body Mass Index (BMI); Year (Yr); African American (AA).

underserved African American population. We also analyzed HbA1c lab results and the number of Emergency Department visits of diabetic patients in the same population and timeframe. We hypothesized that the disruption in everyday life caused by the COVID-19 pandemic might have caused an increased obesity rate, as well as less effective management of diabetes disease manifesting in higher HbA1c values and more frequent ED visits. Our study had mixed results, while some of the models showed significant differences between the pre-pandemic and pandemic timeframes, the measured difference was negligible. It is difficult to assess what parts of the changes shown by our analysis were caused by a long-term trend that would have occurred without the COVID-19 pandemic, and what parts of the changes were caused by the pandemic.

Our analysis reaffirms that the pandemic has affected the African American population more severely than the White population.

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Our most significant finding is that the number of ED visits significantly decreased from 2018 and 2019 to 2020, which can be easily explained by restrictions that were put in place at medical facilities and by the fear of infection at these facilities. These factors likely prevented necessary care seeking and caused harm and death.

The limitations of our research include the short time period investigated. Looking back at a longer period of time before the pandemic, and also having access to more data since the beginning of the pandemic would make it easier to separate the effects of the pandemic from other general trends. Having only one health system's data included in the analysis is also a limitation. Results might be more generalizable if a similar analysis would be performed on larger consolidated datasets, such as the National Covid Cohort Collaborative (N3C) [27].

Future research in this field may include analyzing data from multiple health systems, using a longer time period, and adding more comorbidities in the analysis. Exploring patient behavior related to stress, diet, exercise, and other lifestyle factors is also necessary.

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