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Article

Effectiveness of Telemedicine in Diabetes Management: A Retrospective Study in an Urban Medically Underserved Population Area (UMUPA)

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Abstract: This paper examines the efficacy of telemedicine (TM) technology compared to traditional face-to-face (F2F) visits as an alternative healthcare delivery service for managing diabetes in populations residing in urban medically underserved areas (UMUPAs). Retrospective electronic patient health records (ePHR) with type 2 diabetes mellitus (T2DM) were examined from 1 January 2019 to 30 June 2021. Multiple linear regression models indicated that T2DM patients with uncontrolled diabetes utilizing TM were similar to traditional visits in lowering hemoglobin (HbA1c) levels. The healthcare service type significantly predicted HbA1c % values, as the regression coefficient for TM (vs. F2F) showed a significant negative association (B = −0.339, $p < 0.001$), suggesting that patients using TM were likely to have 0.34 lower HbA1c % values on average when compared with F2F visits. The regression coefficient for female (vs. male) gender showed a positive association (B = 0.190, $p < 0.034$), with HbA1c % levels showing that female patients had 0.19 higher HbA1c levels than males. Age (B = −0.026, $p < 0.001$) was a significant predictor of HbA1c % levels, with 0.026 lower HbA1c % levels for each year's increase in age. Black adults (B = 0.888, $p < 0.001$), on average, were more likely to have 0.888 higher HbA1c % levels when compared with White adults.

Keywords: telemedicine; telehealth; healthcare; information technology; electronic health records; clinical informatics; traditional healthcare; face-to-face (F2F); healthcare access; health disparities; health inequities; diabetes mellitus type 2 (T2DM); urban medically underserved populations; marginalized communities; vulnerable populations; social determinants of health

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1. Introduction

The United States (US) has a high prevalence of diabetes, affecting over 38 million people, which is approximately 10.5% of the population, including 29 million diagnosed and 9 million undiagnosed [1]. Diabetes is the seventh leading cause of death in the US [1,2], with cardiovascular disease as the primary contributor [3]. Medical expenditures in 2017 for diagnosed diabetes were estimated at USD 327 billion from direct and indirect costs [2].

The World Health Organization (WHO) reported the diabetes global mortality rate has risen to the top 10 causes of death; this represents a 70% increase since 2000 [1]. The death rate among males had an 80% increase [2]. The global prevalence of diabetes has nearly doubled since 1980, rising from 4.7% (108 million) to 8.5% (422 million) in 2012 among adults [3,4]. Diabetes prevalence has risen faster in low- and middle-income countries than in high-income countries in the past 10 years [3,4]. The overall mortality rate of 43% among people before they reach the age of 70 is largely attributable to high blood sugar that is higher in low- and middle-income countries [3,4]. The higher than optimal blood glucose levels contributed to the global mortality rate of 2.2 million people by increasing the risks for cardiovascular and other diseases [3,4]. The sobering US national and global statistics on the diabetes epidemic highlight the critical need for this study.

Diabetes management and clinical care have their own share of challenges concerning healthcare access for high-risk groups [5], often resulting in debilitating health outcomes compounded by adverse socio-economic consequences for the overall population [5,6].

The current healthcare system in the United States (US) is primarily structured as a face-to-face (F2F) mode of care, requiring patients to visit a facility, such as a healthcare provider's office or clinic, to manage healthcare needs [7,8]. Traditional F2F visits were the most frequently used healthcare delivery service before the onset of the COVID-19 pandemic [9]. However, F2F healthcare services posed significant barriers for vulnerable populations, particularly during the pandemic [8,10]. Vulnerable populations restricted to only having access to F2F visits for healthcare services experience a significant health threat that could limit the ability to receive essential life-saving and timely treatment [10,11] for effectively managing disease [8]. Significant factors for effectively managing diabetes are the timing of when an individual receives care and the ability to access healthcare services [10,11].

Failing to start or continue therapy, delaying treatment, and missing appointments are known as therapeutic or clinical inertia [12–14], frequently resulting in sustained, high HbA1c glycemic levels, leading to micro- and macrovascular consequences [13–16]. The microvascular (involving small blood vessels–capillaries) and macrovascular (including large blood vessels–arteries and veins) consequences are severe medical conditions [16,17] resulting from uncontrolled HbA1c levels. When people encounter barriers to healthcare services, a cascade of events generally occurs, leading to forestalling or avoiding medical care services [8], which complicates disease management and contributes to adverse health outcomes [16–18].

Telehealth, TM, telemonitoring, remote monitoring, mobile (mhealth) and electronic health (ehealth), telemetric interventions, and virtual encounters are common terminologies that describe informatics technologies [8,19]. The American Telemedicine Association (ATA) makes a distinction between TM and telehealth [19]. Telehealth and TM are terms that are frequently used interchangeably to describe the exchange of medical information for healthcare delivery service when providers and patients are separated by distance and unable to meet in person [8,19]. TM is typically associated with direct remote patient "clinical" services, whereas telehealth encompasses a broader scope of health-related services, including education and remote monitoring [19].

TM interactions can include provider to patient, provider to provider, and patient to ancillary services (health coaching, technicians, and web-based interactive modules) [19]. TM encounters are classified as synchronous, asynchronous, and continuous remote patient monitoring (RPM) [19]. Synchronous communication is live, real-time, and direct (audio-based—mobile or landline phones, or video-internet-based) [19]. Asynchronous communication, also known as store and forward (SF) communication, is defined as previously uploaded medical data used for future transmittal [19]. This study focuses on synchronous TM encounters defined as "real-time" provider to patient communications using audio-based, i.e., mobile or landline phones, or video-internet-based methods [8,19]. The limited number of US-based research articles demonstrates the need for more studies on this crucial topic. Despite the global expansion of TM utilization, few studies have been conducted to demonstrate its effectiveness in diabetes management, with the potential for healthcare access improvement among marginalized populations [8].

Hence, this study is particularly relevant in contributing to the research to assess the effectiveness of interactive, synchronous TM as an alternative resource for healthcare delivery and patient care for marginalized populations [8]. The prospect of expanding TM technology for people living in medically underserved areas (MUAs), where chronic disease rates are high and there is inadequate access to healthcare services, shows promise for relieving health burdens, enhancing quality of life, and lowering medical costs [8].

According to the Department of Health and Human Services (HHS), underserved and vulnerable groups in marginalized communities have distinctive attributes [20]. Populations identified as underserved generally share one or more characteristics if they: receive fewer healthcare services; encounter multiple barriers (financial, cultural, or linguistic) for accessing and receiving essential healthcare services; are unfamiliar with the process of healthcare system delivery; or live in areas that have a scarcity of healthcare facilities and providers [20]. Vulnerable populations commonly have: higher risk factors for health issues or pre-existing conditions; limited livelihood options (financial, educational, or housing); a lack of access to transportation services; and experience of any form of discrimination [20]. The reference population in this study is both vulnerable and underserved [8]. The COVID-19 pandemic resulted in egregious morbidity and mortality rates, overburdening the US healthcare system [8] and limiting patients' access to F2F healthcare services [20,21]. The pandemic catapulted TM technology to the forefront as an alternative healthcare delivery platform [8,21–23]. Therefore, TM technology was identified as a critical driver and instrument for change in the 21st-century healthcare delivery system [23], assisting in delaying the spread of the virulent COVID-19 disease [8,22,23]. The informatics technology, TM, shattered the glass ceiling as a sine qua non for healthcare delivery services in the US [8]. TM emerged as an essential, life-saving means for reducing healthcare access barriers, providing options for people who would otherwise lack timely, adequate medical treatment [8].

Telehealth/TM has grown from modest beginnings and is now recognized by the *Journal of American Medical Informatics* as an essential core curriculum for health and medical informatics [24]. The medical curriculum aims to train medical professionals in utilizing TM informatics technology to expand distance-based healthcare delivery services to improve access to marginalized communities [24].

One of the most difficult challenges for the public health and US healthcare systems is reducing health equity gaps among vulnerable communities [25] and mitigating healthcare access barriers [8]. Even though barriers to healthcare access among racial and ethnic populations are well documented in the literature [7,25], there is limited evidence of successful interventions that provide feasible solutions for populations residing in UMUPAs [8] who are often disproportionately affected by social determinants of health (SDoH) [8,25,26]. According to the CDC, medically underserved areas (MUAs) are in locations characterized by social determinants of health factors (SDoH) and are the foremost contributors to health challenges, limiting access to healthcare services [8,25–27].

Therefore, this research examined several studies to investigate alternative methods of tackling the health equity gap among underserved/vulnerable populations with T2DM. The studies examined numerous systematic reviews (SRs), meta-analyses (MAs), randomized control trials (RCTs), and qualitative investigations from various geographical regions, countries, and time periods [8]. These investigations reported that TM is comparable to traditional visits in terms of its effectiveness in reducing HbA1c % levels in patients with T2DM [28–30]. The investigations, consisting of heterogenous populations, evaluated the effectiveness of TM in comparison to traditional F2F visits for diabetes management and HbA1c % levels. The search included the *Journal of Medical Internet Research* [28], the *World Journal of Diabetes* [29], and the Informatics for Diabetes Education and Telemedicine (IDEATel) [30], which indexed comprehensive, archival studies published over several years [8].

The *Journal of Medical Internet Research* (JMIR), in 2021, conducted a 12-year (2008–2020), comprehensive, systematic literature search on the effectiveness of TM interventions for managing T2DM [28]. The study focused on TM communications between healthcare providers and patients. The interventions included synchronous ("audio/video") [19] and asynchronous ("email, text messaging, and internet/web-based platforms") [19] methods of diabetes management and glycemic control [28]. The JMIR literature search included a total of 99 studies, 82,000 cases, 16,000 patients, and 7 countries, with the results reporting the mean HbA1c decrease of 1.15% with an average HbA1c value of 6.95% [28].

The *World Journal of Diabetes* conducted a review in 2021 of 43 MAs synthesizing RCTs of 31 years (1989–2020) and reported a significant reduction of HbA1c % levels (−0.486%) by extracting data from the difference in mean HbA1c levels [29].

Long-term RCTs for TM case management undertaken by the Informatics for Diabetes Education and Telemedicine (IDEATel) found that patients maintained improvement in HbA1c levels of 0.29% for over 5 years [30]. The IDEATel study population were adults over 55 years, ethnically diverse (African-American and Hispanic), fluent in English or Spanish, Medicare beneficiaries with T2DM, and residing in federally designated MUAs or Health Professional Shortage Areas (HPSAs) of New York State [30].

This paper examines an alternative to traditional F2F healthcare utilizing synchronous TM communications [19], potentially providing a life, limb, and cost-saving strategy for diabetes management [13,17] by improving access to care services for marginalized populations [8]. The term "access" in this study refers to the type of healthcare service (TM or F2F) and its suitability in meeting the needs of UMUPA residents in terms of access to medical treatment [8].

2. Materials and Methods

This study uniquely analyzed retrospective electronic patient health records from 1 January 2019 to 30 June 2021 of T2DM patients with both uncontrolled diabetes and prediabetes, using a quantitative study design.

2.1. Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Boards (IRBs)–Ethics Committees of Georgia Southern University (GSU) and the University of Florida (UF) for studies involving humans. The IRBs at the UF Health System (#IRB202102147) and GSU (# H22O44) approved the study's protocol. Exempt status for chart reviews was approved for secondary PHR data collection. The data collected were archival, retrospective, and originally collected by UF Health EHR for "healthcare operations" or for "public health activities and purposes," according to "45 CFR 164.512(b)" and "45 CFR 164.501." The UF IRB 01 exempt status is defined as secondary research, for which consent was not required. The study did not involve participants enrolled in experimental protocols. No patient identifiable information was received, and the data were collected anonymously by a third party.

2.2. Sample

The study sample included Commonwealth Family Medicine Clinic (CFMC) T2DM patients with uncontrolled diabetes (≥8.0%) and prediabetes (≥5.7–6.8%) to evaluate the effectiveness of diabetes care, measured by changes in HbA1c % levels and comparing TM with the F2F mode of care. Patients with managed or controlled diabetes were excluded from the analyses due to the relative HbA1c % level stability; therefore, they were not the focus of this investigation.

The majority of the empaneled patients in this study live in an urban medically underserved area (UMUPA) in a sub-county of Jacksonville, Florida, Duval County, known as the "Urban Core" or Health Zone 1 (HZ 1). The population in HZ 1 is 80% African American/Black, and 49.5% have Medicaid as their medical insurer [31]. Residents in HZ 1 have extensive diabetes-related health challenges [32] linked to SDoH factors, high rates of obesity and poverty, a prevalence of food deserts, lower SES, and literacy deficiencies [31,32]. In 2019, Duval County had the third highest hospitalization rate for diabetes-related complications among Blacks in Florida, and the eighth highest count (33,842) among all population demographics in Florida [33,34].

2.3. Study Variables

We operationalized the sociodemographic covariates as the patient's age; birth gender; race; ethnicity; provider type/title; medical insurer; appointment status; and five-digit zip code, converted to regions identified as HZs. The small patient populations in the HZs required data aggregation, which were recoded into four groups based on geographic proximity.

Age: The age in years at the date of the visit encounter.

Gender: The birth gender of the research participants, operationalized and recoded into two categories; the variable is operationalized as male and female. Male is the reference category coded, as when comparing the other category (female).

Race/Ethnicity: The patient demographic variable is operationalized into three groups. The variables are coded as: 0 = White; 1 = African American/Black; 2 = Asian/other. The variable White is the reference category, coded as (0) when comparing the other categories.

Medical insurer type: This variable was based on the patient's primary medical insurer/payer for the healthcare visit at the time service was rendered. It was categorized into three groups, operationalized and recoded as Medicaid, Medicare, and Private (self-pay, private, other). We re-coded the variables as 0 = Medicare, 1 = Medicaid, and 2 = Private/other. The variable Medicare is the reference category, coded as (0) when comparing the other categories. * Note: The US federal health insurance programs Medicare and Medicaid are overseen by the Centers for Medicare & Medicaid Services (CMS). Medicare is the insurance available to people 65 and older, as well as individuals with particular disabilities or conditions. Medicaid insurance is a jointly managed federal-state program that assists individuals with limited resources and low incomes in paying for medical expenses [35].

HealthZones (HZs) in Duval County identified as five-digit zip codes: The HZ variable is operationalized as populations residing in Duval County in different regions, and they were initially coded, identified, and numbered as HZs 1 through 6. These regions were labeled HZ 1–Urban Core (MUA)*, HZ 2–Greater Arlington, HZ 3–Southeast, HZ 4–Southwest (SW), HZ 5–Rural–Outer Rim (MUA)*, and HZ 6–Beaches. The HZs were subsequently reorganized and given new names, according to the geographical location or proximity and to adjust for the small population sizes. The condensed, recoded regions were assigned names and listed in descending order according to each area's population size: HZ MUA, HZ SW, HZs Outer Duval County, and Out of Area.

The HZ MUA, which has a total patient population of 60% and is situated in medically underserved areas of Duval County, combines two HealthZones: 1 and 5 [HZ 1–Urban Core (n = 52%) and 5-Rural–Outer Rim (n = 8%)]. * The HZ SW remained in its own category with 32% of the clinic's population. The HZs in Outer Duval County included 12% of the total clinic population and contain three HealthZones: 2, 3, and 6 [HZ 2–Greater Arlington (n = 3%), HZ 3–Southeast (n = 0.8%), and HZ 6–Beaches (n = 0.5%)]. Out of Area patients represented 4% of the clinic's patient pool. They lived in another state or a non-local region of Florida; thus, they were not in any HZ and were, therefore, omitted. The majority of the empaneled patients in the CFMC reside in a Duval County sub-county identified as HZ1, the Urban Core. The HZ SW was the reference category when comparing the other covariates. Note: * denotes medically underserved areas.

Provider Type (Title): This variable is the title/type of provider conducting the patient visit, operationalized as Medical Doctor (MD), Nurse Practitioner (NP), and Physician's Assistant (PA). The NP is the reference category, coded as (0) when comparing the other categories.

Medical appointments: The type of healthcare service was either TM or F2F visits. TM appointments were conducted through synchronous consultations with a healthcare professional using real-time, audio/video communication [8,19].

2.4. Statistical Methods

The first steps included cleaning, recoding, and examining the primary dataset for missing data and outliers. After examination of the data, imputation was performed on 7 missing lab values, and 21 patients were removed because they did not fit the criteria and had appointments outside of CFMC. The final baseline cohort resulted in 366 patients with 3749 clinic visits. The next step was identifying and subdividing the primary dataset into separate data subsets based on the patient HbA1c % levels for patients with uncontrolled diabetes (≥8.0%) and prediabetes (≥5.7–6.8%), as well as the type of appointment (TM or F2F).

Analyses were conducted using multiple linear regression (MLR) models for patient visits with uncontrolled diabetes and prediabetes, analyzing the relationship between HbA1c % levels and covariates (age, gender, race, HZ, medical insurance, healthcare service type, and provider type/title). Data were summarized using frequency and percentages for categorical data.

3. Results Comparing Patient HbA1c % Levels Using TM and F2F Healthcare

3.1. Descriptive Statistics for Patients with Uncontrolled Diabetes and Prediabetes

Frequencies and percentages for the categorical variables of all patients with uncontrolled diabetes (*n* = 1685) and prediabetes visits (*n* = 634) are displayed in Table 1. The demographics reporting the highest numbers and percentages for patients with uncontrolled diabetes were Black (*n* = 1234, 73.23%), non-Hispanic (*n* = 1668, 98.99%), female (*n* = 1014, 60.18%) patients living in medically underserved areas (MUAs–HZ 1 and HZ 5) (*n* = 917, 54.42%); the highest number of visits were with the NP (*n* = 1087, 64.51%). Medicaid (*n* = 698, 41%) was the most common type of medical insurance. Patients used both types of healthcare visits equally, as 843 were F2F visits (50.03%) and 842 patients utilized TM appointments (49.97%).

Table 1. Descriptive Statistics for T2DM patient visits with uncontrolled diabetes and prediabetes.

Characteristics	Uncontrolled N	Uncontrolled %	Prediabetes N	Prediabetes %
Ethnicity				
Hispanic	17	1.01	35	5.52
Non-Hispanic	1668	98.99	599	94.48
Provider Title				
MD	272	16.14	175	27.6
PA	326	19.35	149	23.5
NP	1087	64.51	310	48.9
Gender				
Male	671	39.82	171	26.97
Female	1014	60.18	463	73.03
HealthZones				
Outer Duval	65	3.86	48	7.57
Out of Area *	87	5.16	27	4.26
Southwest (SW)	616	36.56	231	36.44
MUAs	917	54.42	328	51.74
Race				
Other	30	1.78	35	5.52
White	421	24.99	183	28.86
Black	1234	73.23	416	65.62
Medical Insurer				
Private	291	17.27	89	14.04
Medicare	696	41.31	306	48.26
Medicaid	698	41.42	239	37.70
Healthcare service type				
Telemedicine (TM)	843	50.03	311	49.05
Traditional (F2F)	842	49.97	323	50.95

* Not in a HealthZone region.

The demographics reporting the highest numbers and percentages of patients with prediabetes were Black (*n* = 416, 66%), Non-Hispanic (*n* = 599, 94.5%), female (*n* = 463, 73%), and living in MUAs (*n* = 328, 52%), and they had the highest number of visits with the NP (*n* = 310, 49%). The number of healthcare service visits was approximately equal in F2F (n = 323, 50.95%) and TM appointments (n = 311, 49.05%). Medicare (n = 306, 48.3%) was the most common type of medical insurance. The mean age of the patients was 59.4 years (SD) = 11.65.

3.2. Tables

3.2.1. Patients with T2DM Uncontrolled Diabetes Visits

The MLR model for patients with T2DM uncontrolled diabetes visits analyzed the HbA1c % levels and covariates (age, gender, race, provider type/title, healthcare service, medical insurer, and HZs), indicating significance (Table 2) F(8, 1676) = 25.781, $p < 0.001$, $R^2 = 0.105$. The R^2 for the overall model reports an effect size of 0.105, indicating that approximately 10.5% of the variance in HbA1c % levels is explainable by the covariates in the model.

Table 2. Multiple Linear Regression Model Analyzing HbA1c % Levels and Covariates.

Characteristics	Unstandardized Coefficients		T	*p*-Value
	B (Regression Coefficient)	Std. Error		
(HbA1c %)	**11.588**	0.307	37.765	**0.001**
Age	**−0.026**	0.004	−5.863	**0.001**
Gender-Female	**0.190**	0.090	2.122	**0.034**
Race-Black	**0.888**	0.097	9.117	**0.001**
Provider Type/title-NP	0.006	0.089	0.072	0.942
Healthcare-TM	**−0.339**	0.086	−3.957	**0.001**
Insurer-Medicaid	**−0.612**	0.097	−6.286	**0.001**
HZ SW	**0.617**	0.093	6.638	**0.001**
HZs in Outer Duval	**−0.602**	0.225	−2.678	**0.007**

Note: MLR model was significant F(8, 1676) = 25.781, p <0.001, R^2 = 0.105. **Bold** indicates statistical significance. Unstandardized Regression Equation: HbA1c = 11.588 + age (−0.026) + Gender-Female (0.190) + Race-Black (0.888) + NP (0.006) + Healthcare service-TM (−0.339) + Medicaid (−0.612). + HZ SW* (0.617) + HZ Outer Duval (−0.602).

The results of the MLR model for patients with T2DM uncontrolled diabetes visits were significant at $p < 0.001$ (Table 2). The healthcare service type TM significantly predicted HbA1c % values, as the regression coefficient for TM (vs. F2F) showed a significant negative association (B = −0.339, $p < 0.001$), suggesting that controlling for other covariates in the model, patients using TM were likely to have 0.34 lower HbA1c % values on average when compared to F2F visits. The regression coefficient for the gender category female (vs. male) showed a significant positive association (B = 0.190, $p < 0.034$) with HbA1c % levels, showing that female patients had 0.19 higher HbA1c % levels than males.

Age (B = −0.026, $p < 0.001$) was a significant predictor of HbA1c % levels, which indicated 0.026 lower HbA1c % levels for each year of increase in age. Black adults (B = 0.888, $p < 0.001$), on average, were more likely to have 0.888 higher HbA1c % levels when compared with White adults, after controlling for other covariates in the model. The *HZ SW* (B = 0.617, $p < 0.001$), compared to the MUAs, was on average more likely to have 0.617 higher HbA1c % levels.

The Outer Duval County (B = −0.602, $p < 0.007$) was a significant predictor when compared to the MUAs and a patient was on average likely to have 0.602 % lower HbA1c % levels. The medical insurer Medicaid (B = −0.612, $p < 0.001$) was also a significant predictor. This B coefficient suggests that patients with Medicaid, when compared with Medicare, as their medical insurer on average had 0.612 lower HbA1c % levels. The type of healthcare provider NP (B = 0.006, $p = 0.943$) was not significant when compared with other healthcare providers. The results of the MLR model for T2DM patients with uncontrolled diabetes–HbA1c % levels and the covariates gender, age, race, healthcare service type, provider type, HZs, and medical insurer are reported in Table 2.

3.2.2. Patients with Prediabetes Visits

The MLR model for patients with prediabetes visits analyzed the HbA1c % levels and covariates (age, gender, race, provider type/title, healthcare service, medical insurer, and HZs), indicating significance (Table 3) $F(8, 634) = 8.842$, $p < 0.001$, $R^2 = 0.100$. The R^2 for the overall model reports an effect size of 0.100, indicating that approximately 10% of the variance in HbA1c % levels is explainable by the covariates in the model.

Table 3. Multiple Linear Regression Analyzing HbA1c % Levels and Covariates.

Characteristics	Unstandardized Coefficients		T	*p*-Value
	B (Regression Coefficient)	Std. Error		
(HbA1c %)	**5.880**	0.099	59.618	**0.001**
Age	**0.006**	0.001	4.541	**0.001**
Gender-Female	0.016	0.032	0.488	0.626
Race-Black	**−0.062**	0.029	−2.171	**0.030**
Provider type-NP	0.008	0.028	0.301	0.763
Healthcare-TM	−0.042	0.026	−1.639	0.102
Insurer-Medicaid	**0.237**	0.034	7.010	**0.001**
HZ SW	**0.086**	0.031	2.796	**0.005**
Outer Duval	0.027	0.053	0.499	0.618

Note: MLR model was significant $F(8, 634) = 8.842$, $p < 0.001$, $R^2 = 0.100$. **Bold** indicates statistical significance at $p < 0.05$. Unstandardized Regression Equation: HbA1c = 5.880 + age (0.006) + gender-female (0.016) + Black (−0.062) + HZ SW (0.086) + HZ Outer Duval* (0.027) + Healthcare service-TM (−0.042) + NP (0.008) + Medicaid (0.237).

The patient's age (B = 0.006, $p < 0.001$) was a significant predictor, indicating that, on average, a one-year increase in age will result in a 0.006 increase in HbA1c % level. The race category for Black adults (B = −0.062, $p = 0.030$) was also significantly associated with our outcome when compared to White adults. This suggests that Black adults on average were likely to have HbA1c levels lower by 0.062% when compared to White adults. The patients in HZ SW (B = 0.086, $p = 0.005$) were likely to have an 0.086 higher HbA1c %, compared to those in HZ MUAs. The type of medical insurer Medicaid (B = 0.237, $p < 0.001$) was a significant predictor of HbA1c when compared with Medicare. This suggests that patients with Medicaid were likely to have 0.237 higher HbA1c % levels when compared to Medicare.

After controlling each variable for the other covariates in this model, the variable gender (B = 0.016, $p = 0.626$) was not significantly associated with HbA1c. The healthcare service type TM (B = −0.042, $p = 0.102$) also did not have a significant effect on HbA1c % levels when compared to F2F visits. The HZ Outer Duval County (B = 0.027, $p = 0.618$), when compared with MUAs, was not significantly associated with HbA1c levels. The NP provider type (B = 0.008, $p = 0.763$) was not a significant factor in predicting HbA1c, when compared with other healthcare providers.

3.3. Summary

The MLR model for patients with uncontrolled diabetes indicated there was a significant negative association among age, healthcare service type TM, medical insurer-Medicaid, and Outer Duval County. The gender female, Black race, and HZ SW had a significant positive association with HbA1c % levels. The provider type was not statistically significant.

The MLR model for patients with prediabetes indicates a significant negative association of race with patients' HbA1c % levels. The medical insurer Medicaid and the HZ SW had significant positive associations with HbA1c % levels. The variables gender, healthcare service, HZs in Outer Duval County, and provider type were not statistically significant. Tables 2 and 3 presented the results of the MLR model for patients with uncontrolled diabetes and prediabetes, HbA1c % levels, and the covariates gender, age, race, healthcare service type, provider type, HZs, and medical insurer [8].

4. Discussion

The underlying context of this research was to investigate diabetes management among patients with T2DM, who reside in urban medically underserved areas (UMUPAs) and utilized [TM and F2F] for healthcare services [8]. Populations living in MUA/UMUPAs face significant personal and systemic barriers to obtaining adequate healthcare services [8]. Barriers to healthcare services are extremely problematic for people with chronic illnesses, often leading to complications in disease management and adverse health outcomes [7,36]. Achieving optimal glycemic control by managing HbA1c % levels is critical for people with diabetes to reduce potential micro- and macrovascular complications [16,17,37].

At the time this research was conducted, there was a scarcity of US-based studies that analyzed the efficacy of TM/F2F visits in diabetes management and HbA1c % levels [8]. The limited number of US-based research articles demonstrates the need for more studies on this crucial topic [8]. This study was distinct in several ways; it had a retrospective, quantitative study design, and regression models were used to capture unique, real-time, PHR data [8]. The study uniquely analyzed the health records of patients with prediabetes and uncontrolled T2DM, in one medical clinic, who resided in an UMUPA and had appointments using both modes of healthcare visits (TM technology and F2F) [8]. The research population also had one of the highest rates of chronic disease, hospitalizations, and ER visits related to diabetes in the state of Florida [31,32,34]. In contrast to previous studies that analyzed systematic reviews and meta-analyses, this work used original data from patient health records [8].

The study period range was from January 2019 to June 2021. This period covered pre-Covid and Covid years, which increased TM utilization rates among patients. The patients in this specific clinic with T2DM were the highest TM utilizers [8]. Patients had the option of using either TM or F2F visits, and the study requirements included both visit types during the study period [8]. The subjective reasons for patient's healthcare visit choices can only be speculative without a different research design, such as a qualitative or mixed methods approach. The quantitative, retrospective study design limits the type of data that researchers can acquire, and it does not identify confounding variables. There were fewer patients with prediabetes compared to patients with T2DM. Patients with a prediabetes diagnosis may also have different perspectives on disease management compared to patients with T2DM.

Although there were no comparable US-based studies at the time this research was authored, the final results were consistent with other studies [8,28–30]. The results found a significant association between the utilization of TM, compared with traditional visits, and lower HbA1c % levels ($p < 0.001$) in patients with uncontrolled T2DM, suggesting that TM is an effective diabetes management tool [8] There was no significant association between patients with prediabetes and healthcare service TM utilization ($p = 0.102$), possibly due to the small number of patients available for analyses.

The study had several limitations. The study design limited the ability to obtain precise data endpoints that reflected changes in HbA1c % values at specific time intervals. Obtaining retrospective, secondary data that was initially collected for clinical practice made data extraction challenging for research purposes. Extrinsic factors that may have influenced outcomes were: PHR data that was collected both before and during the COVID-19 pandemic, lifestyle, availability of healthy food options, physical activity, social support, self-efficacy, relational dynamics, medications, stress, and mental health challenges [8].

When diabetes is managed, it offsets future complications related to uncontrolled HbA1c levels. Reductions in the HbA1c levels are significant and can mitigate diabetes-related deaths and micro- and macrovascular complications [15–17] in patients with T2DM [37]. A seminal study conducted for the UK prospective diabetes observational study (UKPDS) analyzed data from 23 hospital clinics in 3 countries (England, Scotland, and Northern Ireland), and it showed that a 1% reduction in mean HbA1c is associated with a 21% reduction in diabetes-related deaths and a 37% reduction in microvascular complications in T2DM patients [16]. Future research may include a mixed methods approach, in which a qualitative component added to this quantitative approach could provide findings that are more applicable to patient care [8]. In a non-pandemic environment, an in-depth assessment of patient perspectives would be possible, such as technology experience and details of their healthcare visit [8]. More studies on prediabetes care are critical to gain information about how TM may serve as a preventative strategy to offset future incidences of T2DM.

5. Conclusions

This study contributes new, relevant, empirical data to the field of health informatics, which is used in clinical settings to improve the provision of healthcare services, particularly in populations most impacted by access barriers. We looked at factors that contribute to optimizing health outcomes utilizing telemedicine, an information technology, to manage T2DM in populations that reside in medically underserved areas with limited access to healthcare services [8].

Patients' HbA1c % levels from the extreme ends of the diabetes spectrum were analyzed, beginning at the earliest development of diabetes (prediabetes) to the latent stage (uncontrolled diabetes) [8]. The goal of the study was to assess the efficacy of utilizing TM compared to F2F visits in diabetes care. Patients with prediabetes and uncontrolled diabetes are at a critical juncture in terms of clinical outcomes [8]. Providing timely prevention and intervention is essential in halting the progression of elevated glycemic levels, thus lowering the potential for developing complications [8,37].

TM provides practitioners with real-time data using technology to continuously monitor patients. It also provides patients with an effective means of receiving access to timely and potentially life-saving healthcare services. Evidence suggests that improving access to healthcare by enhancing delivery services for people with T2DM can reduce disease management complications [37], which leads to higher morbidity and mortality rates.

Healthcare providers must advance beyond the former gestalts of disease-oriented, tertiary care and implement preventative care solutions to combat the growing global diabetes epidemic. Therefore, finding alternative, evidence-based, scalable interventions for healthcare services is imperative as a preemptive strategy to address the current and future needs of the population's health [8].

The study's findings may also support healthcare facilities and medical clinics in customizing interventions using informatics technology to improve care for patients with other chronic illnesses and reduce health disparities among communities impacted by social determinants of health.

Despite the study's limitations, we anticipate that future studies will be conducted as a result of our research, because it was a novel study that addressed a critically important and urgent topic in disease management, particularly in marginalized regions.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Georgia Southern University and the University of Florida for studies involving humans. Ethical Approval–Institutional review boards (IRBs) at the UF Health System IRB 01 on 18 October 2021 and Georgia Southern University exemption 4-(limited review) approved the study protocol on 20 October 2021. Exempt status for chart reviews was approved for secondary PHR data collection. The data collected was archival, retrospective, and originally collected by UF Health EHR EPIC for "healthcare operations" according to 45 CFR 164.512(b). The UF IRB 01 exempt status is defined as secondary research, for which consent was not required. The study did not involve participants enrolled in experimental protocols and should pose minimal risk to administrative health professionals or patients. No patient identifiable information was received, and the data were analyzed anonymously.

Informed Consent Statement: Patient consent was waived due to secondary research. Secondary research for which consent is not required: The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b).

Data Availability Statement: Restrictions apply to the availability of these data. Data was obtained from [UF Health] and are available [health.ufl.edu] with proper permission from [UF Health]. Data was obtained from University of Florida Health and not publically available due to patient privacy issues.

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