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Original Article

Investigating Racial Disparities in Insulin Pump Use Among People with Type 1 Diabetes Across the United States: A Retrospective Multicenter Study

Mahmoud Nassar[1], Ahmed Y. Azzam[2], Mahmoud M. Morsy[3], Iqra Patoli[1], Angad Gill[1], Erlin J. Marte[4]*

1- Department of Medicine, Division of Endocrinology, Diabetes and Metabolism, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, New York, USA.
2- Montefiore-Einstein Cerebrovascular Research Lab, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA.
3- Faculty of Medicine, October 6 University, 6th of October City, Giza, Egypt.
4- Chief of Endocrinology, Director of Endocrine and Diabetes Department at VA Western New York Health Care, Veterans Affairs, Buffalo, NY, USA.

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ABSTRACT

Introduction: Despite technological advances in Type 1 Diabetes Mellitus (T1D) management, racial disparities in insulin pump utilization persist. We investigated patterns of insulin pump adoption across different racial groups using a large-scale, multi-institutional database to quantify these disparities and identify potential intervention points.

Methods: We conducted a retrospective cohort study using the TriNetX research network, analyzing data from 978,665 T1D patients across 66 healthcare organizations. Propensity score matching was employed to balance cohorts, with a focused sub-analysis of Buffalo, NY (n=6,080) to examine regional variations in comparison to the United States nationwide present data.

Results: Nationwide data revealed significant racial disparities in insulin pump utilization, with White patients showing the highest adoption rate (11.74%) compared to Black or African American (AA) patients (4.056%). Buffalo cohort demonstrated higher overall adoption rates but maintained similar disparity patterns (White: 30.18%, Black or AA: 13.75%). Post-matching analysis confirmed these disparities persisted independent of demographic factors.

Conclusions: Our findings reveal significant racial disparities in insulin pump adoption, with regional variations suggesting the influence of institutional factors. These results highlight the need for targeted interventions to promote equitable access to diabetes technology and prevent the widening of health disparities in T1D care.

* ***Corresponding author:*** *Mahmoud Nassar, MD, PhD, Department of Medicine, Division of Endocrinology, Diabetes and Metabolism, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, New York, USA. Email Address: Dr.Nassar@aucegypt.edu*

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1. Introduction

Type 1 Diabetes Mellitus (T1D) management has been revolutionized by advanced technologies, particularly insulin pumps, which have demonstrated significant improvements in glycemic control, quality of life, and reduction of diabetes-related complications [1]. However, despite these well-documented benefits, we continue to observe substantial disparities in access to and utilization of these vital technologies across different racial and ethnic groups in the United States [2].

The previous and current literature evidence have highlighted concerning patterns of inequitable access to diabetes technology [3], with studies suggesting that racial and ethnic minorities face disproportionate barriers to insulin pump adoption. These disparities persist even when controlling for socioeconomic factors and insurance coverage, indicating deeper systemic issues in healthcare delivery and access [4]. While existing literature has documented these disparities, comprehensive analyses of large-scale [5], multi-institutional data examining racial patterns in insulin pump utilization remain limited [6]. Understanding and addressing these disparities has become increasingly crucial as diabetes technology continues to advance. Recent studies have shown that early adoption of insulin pump therapy is associated with better long-term outcomes, including reduced rates of diabetic ketoacidosis, severe hypoglycemia, and diabetes-related hospitalizations [7]. However, if certain racial and ethnic groups systematically experience delayed access to or reduced utilization of these technologies [8], we risk perpetuating and potentially widening existing health disparities in diabetes care [9].

Our study aims to provide a comprehensive analysis of racial disparities in insulin pump utilization among adults with T1D across the United States, leveraging data from a large network of healthcare organizations. By highlighting and addressing both nationwide patterns and focused regional data from Buffalo, New York, we aim to understand how these disparities manifest at different geographic and institutional levels using the TriNetX database; The TriNetX database and research network represents a federated health research platform that integrates de-identified electronic health records from several healthcare organizations across the United States, providing real-world data from over 197 million unique patient records. This network enables large-scale observational studies through standardized data collection and analysis tools while maintaining compliance with privacy regulations and institutional policies [9].

This dual-perspective approach allows us to identify both broad systemic patterns and local variations in technology access and adoption. The significance of our study is concerned about its potential to inform targeted interventions and policy changes. By quantifying the extent of racial disparities in insulin pump utilization and identifying specific patterns across different healthcare settings, we can better understand where interventions are most needed.

2. Methods

2.1. Study Design and Data Source:

We conducted a retrospective cohort study utilizing the TriNetX research network platform (TriNetX Inc., Cambridge, MA, USA), a federated health research network that aggregates de-identified electronic health records from 66 healthcare organizations across the United States (https://trinetx.com/solutions/live-platform/). The study period concluded with data extraction on September 25, 2024, employing a standardized query approach through the TriNetX platform to identify eligible participants and extract relevant clinical and demographic data.

2.2. Study Population:

The study population comprised adults (⩾18 years) with a confirmed diagnosis of T1D, identified using International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) code E10. Participants were stratified into two distinct cohorts based on their insulin delivery method: individuals using insulin pump therapy (pump cohort, n=84,903) and those not using insulin pump therapy (no pump cohort, n=893,762), forming an initial nationwide sample of 978,665 patients. Insulin pump usage was identified through Current Procedural Terminology (CPT) codes and medical device records within the electronic health record system. Additionally, data on Continuous Glucose Monitoring (CGM) utilization was collected.

2.3. Data Collection and Variables:

Demographic and clinical data collection encompassed age (calculated at the time of data extraction), sex (male/female), and self-reported race/ethnicity. Race and ethnicity categories followed U.S. Census Bureau classifications, including White, Black or African American (AA), Hispanic or Latino, Asian, Native Hawaiian or Other Pacific Islander, and American Indian or Alaska Native. Clinical variables included insulin pump usage status and comprehensive healthcare utilization metrics.

2.4. Statistical Analysis:

Our statistical approach employed propensity score matching to minimize selection bias and ensure robust analysis. We implemented 1:1 matching considering age, sex, and race/ethnicity as covariates, resulting in balanced cohorts of 84,723 patients each. Post-matching balance was confirmed with standardized mean differences less than 0.1 for all variables. Descriptive statistics were calculated with continuous variables presented as means ± standard deviations and categorical variables as frequencies and percentages. Between-group comparisons utilized Chi-square tests for categorical variables and Student's t-tests for continuous variables, with statistical significance set at $p<0.05$. To evaluate factors associated with pump utilization, we performed multivariate logistic regression analyses, adjusting for potential confounders including age, sex, and race/ethnicity, with results presented as adjusted odds ratios and 95% confidence intervals.

2.5. Geographic Sub-analysis:

A focused sub-analysis was conducted on a cohort from Buffalo, New York (n=6,080) to examine regional variations in insulin pump utilization patterns. This analysis employed identical statistical methodologies, with propensity score matching yielding 1,360 patients per group, matched for age, sex, and race/ethnicity, followed by comparative analyses between matched cohorts.

2.6. Ethical Approvals:

The study protocol received exemption from the University at Buffalo Institutional Review Board (IRB) committee (STUDY00007618). Data handling and analysis adhered to Health Insurance Portability and Accountability Act (HIPAA) guidelines, with the use of de-identified data through the TriNetX platform ensuring protection of patient privacy, compliance with federal regulations, and maintenance of data integrity.

3. Results

3.1. Baseline Characteristics:

In our nationwide cohort, we initially identified 978,665 eligible participants, comprising 84,903 patients in the pump cohort and 893,762 in the no-pump cohort (Table 1). Before propensity score matching, we

Table 1: Demographic Characteristics Before and After Propensity Score Matching in the U.S.-based cohort.

Characteristics	Before Matching			After Matching		
	No Pump (n=893,762)	Pump (n=84,903)	P-value	No Pump (n=84,723)	Pump (n=84,723)	P-value
Sex, n (%)						
Female	356,119 (48.56)	43,810 (54.41)	<0.0001	43,820 (54.41)	43,810 (54.41)	0.9612
Male	377,182 (51.44)	36,723 (45.59)	<0.0001	36,730 (45.59)	36,723 (45.59)	0.9726
Age (years)						
Current Age, mean ± SD	58.5 ± 21.9	40.3 ± 20.9	<0.0001	40.3 ± 20.9	40.3 ± 20.9	0.9546
Race/Ethnicity, n (%)						
White	464,764 (67.37)	65,453 (85.12)	<0.0001	65,477 (85.12)	65,453 (85.12)	0.8894
Black / African American	124,058 (17.98)	5,999 (7.80)	<0.0001	5,997 (7.80)	5,999 (7.80)	0.9849
Hispanic or Latino	74,688 (10.83)	4,344 (5.65)	<0.0001	4,336 (5.63)	4,344 (5.65)	0.9298
Asian	15,678 (2.27)	1,065 (1.38)	<0.0001	1,058 (1.38)	1,065 (1.38)	0.8785
Native Hawaiian or Other Pacific Islander	8,474 (1.23)	455 (0.59)	<0.0001	450 (0.58)	455 (0.59)	0.8676
American Indian or Alaska Native	3,395 (0.32)	217 (0.28)	<0.0001	200 (0.26)	217 (0.28)	0.4046

SD: Standard Deviation; n: Number (sample size); P-value: Probability Value

Table 2: Demographic Characteristics Before and After Propensity Score Matching in Buffalo cohort.

Characteristics	Before Matching			After Matching		
	No Pump (n=4,500)	Pump (n=1,580)	P-value	No Pump (n=1,360)	Pump (n=1,360)	P-value
Sex, n (%)						
Female	2,180 (48.44)	760 (48.10)	0.8143	640 (47.06)	670 (49.27)	0.2496
Male	2,070 (46.00)	760 (48.10)	0.1497	680 (50.00)	650 (47.79)	0.2498
Age (years)						
Current Age, mean ± SD	50.4 ± 24.7	27.9 ± 16.7	<0.0001	29.6 ± 17.6	29.5 ± 17.3	0.9187
Race/Ethnicity, n (%)						
White	3,040 (67.56)	1,310 (82.91)	<0.0001	1,100 (80.88)	1,100 (80.88)	1.0000
Black / African American	700 (15.56)	110 (6.96)	<0.0001	110 (8.09)	110 (8.09)	1.0000
Hispanic or Latino	230 (5.11)	70 (4.43)	0.2825	50 (3.68)	60 (4.41)	0.3304
Asian	60 (1.33)	30 (1.90)	0.1094	30 (2.21)	20 (1.47)	0.1535
American Indian or Alaska Native	40 (0.89)	10 (0.63)	0.3324	10 (0.74)	10 (0.74)	1.0000

SD: Standard Deviation; n: Number (sample size); P-value: Probability Value

Table 3: Prevalence of Insulin Pump and CGM Usage by Race in the USA and Buffalo, New York (2010-2024) among patients with T1D.

Race/Ethnicity	Insulin pump		CGM	
	USA	Buffalo	USA	Buffalo
White	11.74%	30.18%	11.55%	11.98%
Asian	5.79%	37.50%	8.92%	12.50%
Native Hawaiian or Other Pacific Islander	5.09%	100%	1.87%	0%
American Indian or Alaska Native	5.52%	20%	7.34%	20%
Unknown Race	5.01%	17.28%	6.59%	7.41%
Black or African American	4.06%	13.75%	6.20%	6.25%

T1D: Type 1 Diabetes; CGM: Continuous Glucose Monitoring; USA: United States of America

observed significant demographic differences between the cohorts (all p<0.0001). The pump cohort was notably younger (mean age 40.3 ± 20.9 years vs 58.5 ± 21.9 years) and had a higher proportion of female patients (54.41% vs 48.56%). We found substantial racial/ethnic disparities in pump utilization, with White patients representing a markedly higher proportion of the pump cohort compared to the no-pump cohort (85.12% vs 67.37%). Conversely, Black or AA (7.80% vs 17.98%), Hispanic or Latino (5.65% vs 10.83%), and Asian patients (1.38% vs 2.27%) were underrepresented in the pump cohort.

After propensity score matching, we achieved well-balanced cohorts of 84,723 patients each, with no significant differences in demographic characteristics (all p>0.05). In the matched cohorts, both groups maintained identical distributions of sex (54.41% female), age (40.3 ± 20.9 years), and racial/ethnic composition (White: 85.12%, Black or AA: 7.80%, Hispanic or Latino: 5.63-5.65%, Asian: 1.38%).

Our Buffalo sub-analysis included 6,080 patients (pump: n=1,580; no-pump: n=4,500) before matching (Table 2). Similar to our nationwide findings, we observed significant pre-matching disparities. The pump cohort was younger (27.9 ± 16.7 years vs 50.4 ± 24.7 years, p<0.0001) and showed comparable gender distribution (48.10% female vs 48.44%, p=0.8143). Racial disparities were evident, with White patients comprising a larger proportion of the pump cohort (82.91% vs 67.56%, p<0.0001) and Black or AA patients being underrepresented (6.96% vs 15.56%, p<0.0001).

Following propensity score matching in the Buffalo cohort, we achieved balanced groups of 1,360 patients each, with no significant demographic differences (all p>0.05). The matched cohorts showed comparable age (pump: 29.5 ± 17.3 years; no-pump: 29.6 ± 17.6 years), gender distribution (pump: 49.27% female; no-pump: 47.06%), and racial/ethnic composition (White: 80.88%, Black or AA: 8.09%, Hispanic or Latino: 3.68-4.41%).

3.2. Nationwide vs. Buffalo Comparison:

In our analysis of insulin pump and CGM usage across different racial groups, we observed significant disparities in adoption rates both nationally and in Buffalo. Our findings revealed substantial variations in technology utilization across racial and ethnic groups, with particularly notable differences in insulin pump usage (Table 3).

At the national level, we found that White individuals had the highest insulin pump adoption rate at 11.74%, markedly higher than all other racial groups. In contrast, Black or AA individuals showed the lowest insulin pump utilization rate at 4.056%, representing a nearly threefold difference. Other racial groups demonstrated intermediate adoption rates: Asian (5.79%), American Indian or Alaska Native (5.52%), Native Hawaiian or Other Pacific Islander (5.09%), and individuals of Unknown Race (5.01%).

While looking at Buffalo specifically, we observed generally higher adoption rates across all racial groups compared to national averages, though racial disparities persisted. In Buffalo, White individuals maintained the highest insulin pump usage rate at 30.18%, while Black or AA individuals showed a usage rate of 13.75%. Considerably, Asian individuals in Buffalo demonstrated a relatively high adoption rate of 37.5%.

When it comes to CGM usage, similar patterns of disparity were evident. Nationally, White individuals showed the highest CGM adoption rate at 11.55%, while Black or AA individuals had substantially lower usage at 6.2%. Asian individuals demonstrated relatively higher CGM adoption at 8.92%, followed by American Indian or Alaska Native (7.34%), Unknown Race (6.59%), and Native Hawaiian or Other Pacific Islander showing the lowest rate at 1.873%. In the Buffalo system, CGM adoption patterns showed some variation from national trends. White individuals maintained relatively high usage at 11.98%, while Asian individuals showed adoption rates of 12.5%. Black or AA individuals in

Buffalo system had CGM usage rates of 6.25%, similar to national figures. American Indian or Alaska Native individuals showed higher adoption at 20%, though this finding should be interpreted cautiously given potential sample size limitations.

It is demonstrated that there are persistent racial disparities in diabetes technology adoption within the United States, with particularly pronounced differences in insulin pump usage between White and Black or AA individuals, both nationally and regionally.

4. Discussion

Our study reveals significant racial disparities in insulin pump utilization among individuals with T1D across the United States, with particularly pronounced differences between White and Black or AA populations. These findings carry significant clinical implications, given that insulin pumps provide more precise insulin delivery and reduce risks of both hypoglycemia and hyperglycemia compared to MDI [10]. The integration of insulin pumps with CGM systems, enabling automated insulin delivery adjustments, further amplifies the importance of adoption rates, highlight multiple barriers to insulin pump access. These include high initial and ongoing costs [18], technical complexity requiring comprehensive education [19], and challenges related to healthcare provider biases [20]. The impact of these barriers is particularly pronounced among Black or AA populations, who often face additional socioeconomic challenges [21] and healthcare access limitations [22]. Geographic variations in our data, particularly between national and Buffalo-specific cohorts, suggest that local healthcare delivery systems significantly influence technology access [23]. The higher overall adoption rates in the Buffalo cohort, while encouraging, also demonstrate that addressing systemic barriers [24] and insurance coverage issues [25] may help reduce but not eliminate racial disparities. The lower insulin pump utilization rates among racial minorities likely contribute to poorer health outcomes [26], as previous studies have shown that limited access to advanced diabetes technologies is associated with higher rates of complications [27]. Our findings of persistent disparities, even after controlling for demographic factors, is consistent and parallel with some of the literature studies [28] showing that socioeconomic status alone does not fully explain these gaps [29]. To address these disparities, our results suggest the need for multilevel interventions. These should include improving insurance coverage, enhancing provider education about cultural competency, and developing targeted outreach programs for underserved communities [30]. The higher adoption rates in our Buffalo cohort, while still showing racial disparities, suggest that institutional policies and focused efforts to improve access can have positive impacts.

Our study has important considerations and future directions for clinical practice and health policy. First, healthcare systems should implement systematic approaches to evaluate and address barriers to insulin pump adoption among racial minorities. Second, provider education should emphasize both the technical aspects of insulin pump therapy and cultural competency in technology prescription. Third, insurance policies should be reviewed and modified to ensure equitable access to diabetes technologies.

The limitations of our study include its retrospective nature, potential selection bias in the TriNetX database, and inability to capture detailed socioeconomic factors or insurance status. Additionally, while our regional analysis provides valuable insights, the smaller sample sizes for certain racial groups may limit generalizability. Future studies should focus on prospective studies examining the impact of targeted interventions to reduce racial disparities in insulin pump adoption. Additionally, investigation of successful institutional policies and practices that have reduced disparities could provide valuable guidance addressing these disparities [11].

The disparity patterns we observed align with previous research demonstrating that advanced diabetes technologies significantly enhance glycemic control [12] and reduce adverse events [13]. Our findings of lower insulin pump adoption rates among racial minorities are particularly concerning given that CGM use has been associated with improved self-management and enhanced quality of life [14], with continuous application leading to reduced HbA1c levels and decreased glucose variability [15]. The contrast in insulin pump utilization between White (11.74%) and Black or AA individuals (4.056%) in our nationwide cohort reflects broader systemic inequities in healthcare access. These differences persist despite evidence that insulin pump therapy provides more stable glycemic control [16] and significantly reduces HbA1c levels compared to MDI [17]. The higher adoption rates observed in Buffalo cohort (White: 30.18%, Black or AA: 13.75%) suggest that regional variations and institutional factors may influence technology access, though racial disparities remain evident.

Our findings of persistent disparities, even in settings with higher overall

for broader implementation. These findings underscore the urgent need for systematic changes to address racial disparities in diabetes technology access. While technological advances continue to improve diabetes management capabilities, ensuring equitable access to these technologies remains a critical challenge requiring coordinated efforts from healthcare providers, institutions, and policymakers.

5. Conclusions

Our comprehensive analysis of racial disparities in insulin pump utilization among T1D patients reveals systemic inequities that require urgent attention. The present contrast in adoption rates between racial groups, particularly the threefold difference between White and Black or AA populations, suggests that technological advances in diabetes care may inadvertently widen existing health disparities if access barriers remain unaddressed. The regional variations observed between our nationwide and Buffalo cohorts provide valuable insights into the potential impact of institutional policies and local healthcare delivery systems. While higher overall adoption rates in the Buffalo cohort demonstrate that targeted interventions can improve access, the persistence of racial disparities even in this setting underscores the need for more comprehensive solutions. We propose a three-tiered approach to address these disparities: implementing systematic screening for technology eligibility across all racial groups, developing culturally competent diabetes education programs, and establishing institutional policies that prioritize equitable access to diabetes technologies. Future research should focus on evaluating the effectiveness of these interventions and identifying additional strategies to promote equitable adoption of insulin pump therapy.

Conflicts of Interest:
N/A.

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Institutional Review Board (IRB) Approval:
The IRB Board at the Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, NY, USA approved the study protocol

and waived the need for IRB approval given the study design and study type.

LLM Statement:

We have employed an advanced Large Language Model (LLM) to enhance and refine the English-language writing. This process focused solely on improving the text's clarity and style, without generating or adding any new information to the content.

Authors Contribution Statement:

MN conceptualized the study and developed the methodology, with AYA leading the investigation alongside MMM; MN and AYA performed data analysis, while IP, AG, and EM contributed to data curation; MN prepared the original draft; MN and AYA created the visualizations; MN supervised the project and provided administrative oversight; all authors participated in manuscript review and editing, validated the findings, and approved the final version of the manuscript.

Data Availability Statement:

Available on TriNetX Database Based on Institutional Collaborations.

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