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Efficacy of diabetes specialist nurse-led remote care in community clinics: a retrospective cohort study

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Abstract

Background This study evaluates the impact of a diabetes specialist nurse intervention on clinical outcomes and healthcare utilization among patients with diabetes.

Methods A cohort of 452 patients was observed from 2019 to 2022. Clinical metrics such as HbA1C levels and BMI, as well as healthcare utilization patterns, were analyzed before and after the intervention. The intervention was conducted mostly during the COVID-19 pandemic.

Results There was a modest reduction in HbA1C levels, though this change was not statistically significant. Remote visits to primary care physicians increased significantly, reflecting a shift towards telemedicine. The intervention did not significantly alter BMI values, which remained stable despite the aging cohort and progression of the disease. However, In-person visits showed a slight decline, while Diabetes specialists and endocrinologist visits remained unchanged. Annual healthcare costs per patient increased post-intervention.

Conclusions The diabetes specialist nurse intervention positively impacted glycemic control and healthcare utilization, particularly through increased remote consultations. Despite higher healthcare costs, the intervention improved access to care and patient engagement. Further research is needed to assess the long-term sustainability and cost-effectiveness of such interventions.

Keywords Specialist nurse, Diabetes, Remote care, Retrospective cohort study, Community nurse

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder affecting about 250 millions of people worldwide, placing consisting an increasing burden on the healthcare system [1]. As the prevalence of diabetes continues to rise, healthcare providers are exploring **innovative strategies** to manage this complex condition effectively [2]. One such approach involves the integration of diabetes specialist nurses (DSNs) into diabetes care teams, a strategy that has gained significant attention in recent years [3].

Diabetes specialist nurse have emerged as valuable contributors to diabetes management, with a growing body of evidence supporting their effectiveness in various healthcare settings [4, 5]. Studies have demonstrated that NP-led diabetes care can yield outcomes comparable to, and in some cases superior to, those achieved by primary care physicians [2, 6]. For instance, Kuo et al. [2] found that older adults with diabetes who received care from diabetes specialist nurses had lower rates of potentially preventable hospitalizations and emergency department

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visits compared to those under the care of primary care physicians. Additionally, Jackson et al. (2018) reported no clinically significant differences in intermediate diabetes outcomes among patients treated by physicians, diabetes specialist nurses, or physician assistants in the Veterans Health Administration [7].

Beyond routine care, nurse-led interventions have demonstrated additional benefits. Li et al. [8] found significant improvements in diabetes knowledge, self-care behaviors, and glycemic control among patients who received diabetes nurse-led education and follow-up care during and after hospitalization in cardiology services. These findings underscore the potential of diabetes specialist nurses to enhance the quality of diabetes care across diverse healthcare settings [2].

However, as healthcare systems worldwide expand remote services, particularly in response to global health challenges, there is a critical need to evaluate the effectiveness of remote, telemedicine-based diabetes care. The increasing role of telemedicine in chronic disease management, accelerated by the COVID-19 pandemic, presents both opportunities and challenges for diabetes care delivery. While the effectiveness of in-person, nurse-led diabetes care has been well-documented, there is a notable gap in the literature regarding their role in virtual diabetes management.

To address this gap, the present study examined the effectiveness, safety, and clinical outcomes of patients receiving remote follow-up care from a diabetes specialist nurse compared to those receiving standard, in-person diabetes care.

Methods

Study population and control population

Study design

This retrospective cohort study evaluated individuals with DM from January 2019 to December 2022 at Maccabi Healthcare Services (MHS) in Israel, a large healthcare organization that insures over 2.8 million people nationwide. Among these, 180,000 individuals have been diagnosed with DM.

MHS serves both urban and rural populations, providing a broad representation of diabetes care across different geographic areas. While this study did not exclusively focus on rural populations, the intervention aimed to improve access to specialized diabetes care, including for patients in remote and underserved regions where telemedicine could bridge gaps in healthcare access.

Study population

The study focused on patients who received online care from a diabetes specialist nurse between the years 2019–2022 A diabetes specialist nurse is defined as follows:

- A registered nurse with a license to practice nursing.
- Holds an academic master's degree, with at least one degree in nursing.
- Has several years of clinical experience.
- Completed a relevant advanced course in the field of specialty studies.
- Graduated from a diabetes specialty course and met all program requirements.

Control population

The control population consisted of patients from the study period before the intervention of a diabetes specialist nurse (2019–2020). These patients were under the supervision of primary care physicians.

Diabetes Specialist Nurse (DSN) Role & Integration

DSNs operated as part of the primary care team but provided specialized diabetes management remotely rather than being physically embedded within primary care clinics. They collaborated closely with primary care physicians (PCPs) and endocrinologists, offering ongoing monitoring, patient education, medication adjustments, and personalized lifestyle counseling.

Nature of the intervention

The intervention was standardized, with all DSNs following structured protocols for diabetes care, including: (A) Glycemic control monitoring: Regular HbA1C tracking and medication adherence assessments; (B) Personalized treatment adjustments: Collaboration with physicians to modify medications as needed; (C) Patient education: Guidance on nutrition, exercise, and self-care behaviors; and (D) Telemedicine consultations: Scheduled follow-ups through remote platforms to ensure continuity of care.

Data collection

This study employed a comprehensive data collection strategy to gather relevant information on patients receiving diabetes care, with a particular focus on those under the care of diabetes specialist nurses in an online setting. The data collection process was divided into two main components: general data collection at the beginning of the study and specific data collection for the study patients over a four-year period (2019–2022).

General data collection

The first phase of data collection involved gathering general socio-demographic and clinical characteristics of the patients, including:

Socio-Demographic Characteristics (Date of Birth, Gender, Socioeconomic status (SES)); *Clinical Characteristics* (Diabetes diagnosis start date, duration of the disease First online care date appointment with diabetes specialist nurse, Last online care date appointment.with diabetes specialist nurse).

Specific data collection for study patients

The second phase of data collection, focused on detailed healthcare utilization and clinical outcomes for each patient over a four-year period (2019–2022) during the follow up period. This longitudinal data collection allowed for the assessment of trends and changes over time. The following variables were collected for each year:

Healthcare Utilization (Number of in-person visits per year, Number of virtual visits per year, Number of visits to diabetes doctor specialist per year.

- Number of visits to family doctor primary care physician per year (separated divided into in-person and remote visits), Number of visits to diabetes specialist nurse per year (2020–2022 only)).

Clinical Outcomes (BMI (last recorded value each year), Medication adherence (assessed using a traffic light system), Laboratory tests: including Hba1c and urine microalbumin. (last value checked each year), Presence of microalbumin in urine, A1C value).

Economic Data- Patient cost per year medical procedures expenses per year.

Data analysis

Patients' characteristics were presented as n (%) for categorical variables, and as mean *(sd)* [SD] or median (IQR) for normal/non-normal distributed continuous variables. The two same groups (before and after intervention) were tested with chi-square for categorical variables and with Anova or Kruskal-Wallis test as appropriate for normal/nonnormal distributed continues variables.

The two periods were tested with chi-square for categorical variables and with t-test or Mann–Whitney–Wilcoxon test as appropriate for normal/nonnormal distributed continuous variables. The Wilcoxon signed-rank test was used for non-normally distributed continuous variables to compare paired observations before and after intervention (Table 1). To assess relationship between the outcomes and the main variables-of-interest (HbA1C before and after the nurse's intervention), multivariable OLS regression models for HbA1C, adjusted for baseline characteristics with $p < 0.05$ in the univariable test. Sub-analysis in each arrival category separately was performed, with the same covariates. All tests were conducted at a two sided overall 5% significance level (a = 0.05). All analyses were performed using R (R-studio, V.4.0.0, Vienna, Austria). Reference: R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ethical considerations

The study obtained approval from the Health Maintenance Organization's (HMO) ethics committee (Approval No. MHS-0136-23). All data collection procedures ensured anonymity. Nurses offered informed consent before participating, with the assurance of their right to withdraw from the study at any point and for any reason.

Results

Table 2 summarizes the baseline characteristics of the 452 study participants. The median age was 58 years (IQR: 46–70), with a nearly balanced gender distribution (48.5% female). The median time since of diabetes diagnosis duration was 3 years (IQR: 2–4). Cardiovascular diseases were present in 25.4% of participants, while 6.6% had COPD. Lipid profiles were generally within recommended ranges targets for patients with diabetes patients.

Table 1 Comparison of clinical and healthcare service metrics before (2019) and after (2022) the intervention among the same patients ($n = 452$)

	Overall	Before intervention	After intervention	P value
n		452	452	
BMI (median [IQR])	26.40 [22.50, 30.50]	26.65 [22.48, 30.63]	26.10 [22.50, 30.42]	0.411
HbA1C (median [IQR])	7.40 [6.70, 8.30]	7.60 [6.80, 8.50]	7.30 [6.60, 8.10]	0.006
Microalbuminuria (%)	11 (1.2)	5 (1.1)	6 (1.3)	1.000
Annual cost (median [IQR])	18975.00 [9572.00, 33643.00]	17219.00 [7415.75, 29599.00]	21980.00 [11797.50, 37779.00]	< 0.001
Frontal visit - primary care physicians (median [IQR])	6.00 [3.00, 12.00]	7.00 [3.00, 12.00]	5.00 [2.00, 11.00]	< 0.001
Frontal visit - General medical factor (median [IQR])	22.00 [13.00, 35.00]	24.00 [13.00, 36.00]	20.00 [13.00, 33.25]	0.029
Endocrinologist (median [IQR])	2.00 [0.00, 3.00]	2.00 [0.00, 3.00]	2.00 [0.00, 3.00]	0.063
Remote visit - primary care physicians (median [IQR])	4.00 [0.00, 8.00]	2.00 [0.00, 6.00]	6.00 [2.00, 11.00]	< 0.001
Remote visit - General medical factor (median [IQR])	6.00 [2.00, 12.00]	4.00 [1.00, 8.00]	10.00 [5.00, 15.00]	< 0.001

Table 2 Baseline characteristics

	Overall
n	452
Age (median [IQR])	58.00 [46.00, 70.00]
Female (vs. Male)	219 (48.5)
Socioeconomics (median [IQR])	7.00 [5.00, 9.00]
Years diagnosed with diabetes (median [IQR])	3.00 [2.00, 4.00]
COPD (%)	30 (6.6)
Cardiovascular diseases (%)	115 (25.4)
LDL (median [IQR])	76.60 [57.00, 98.00]
HDL (median [IQR])	45.50 [37.00, 59.00]
Cholesterol (median [IQR])	152.00 [123.75, 176.25]
TG (median [IQR])	103.00 [69.75, 165.00]

Comparison of characteristics before and after intervention

Table 3 presents the within-group differences before and after the intervention across the years 2019 to 2022. The *P for trend* indicates whether there is a significant trend over the years within each group, while the *P-value* reflects the differences between the years within each group.

Regarding the population structure, the total number of patients each year was consistently 452. before the beginning of the study all 452 patients had not received any intervention from a diabetes specialist nurse, indicating that the intervention had not yet been implemented that year. By 2022, all 452 patients had undergone the intervention, demonstrating full implementation of the diabetes specialist nurse program across the entire patient cohort. For instance, in 2020, there were 228 patients before the intervention and 224 patients after the intervention, reflecting the gradual rollout of the program during that year. This progression illustrates that as the intervention was introduced over the years, more patients received it, culminating in complete coverage by 2022.

The intervention had a modest impact on clinical outcomes but significantly influenced healthcare utilization patterns as presented in Table 3. Clinical metrics, such as BMI and HbA1C, remained relatively stable. The median BMI showed no significant variation, staying at 26.60 before the intervention and 26.20 afterward. Similarly, HbA1C levels saw only a slight decrease with no statistically significant difference.

While clinical outcomes remained unchanged, the intervention notably affected healthcare usage.

Remote visits to primary care physicians and general medical practitioners increased significantly after the intervention, indicating a shift towards telemedicine. Remote primary care physician visits rose from a median of 3.00 (IQR: 0.00–8.00) before to 6.00 (IQR: 2.00–11.00) after ($p = 0.926$, p-trend = 0.884). Similarly, remote general medical visits increased from 5.00 (IQR: 2.00–10.00) before to 10.00 (IQR: 5.00–16.00) after ($p = 0.001$, p-trend = 0.002).

Conversely, in-person visits declined slightly, though these changes were not statistically significant. Endocrinologist visits remained largely unchanged.

Table 1. presents the overall outcomes of key clinical and healthcare utilization metrics for the same cohort of patients, comparing their status before the intervention in 2019 to after the intervention in 2022. The statistical tests applied were paired, as the same group of 452 patients was measured both before and after the intervention.

There was a statistically significant improvement in HbA1C levels, decreasing from a median of 7.60 [IQR: 6.80–8.50] before the intervention to 7.30 [IQR: 6.60–8.10] after the intervention ($p = 0.006$), indicating better glycemic control. The intervention had no significant effect on BMI, which remained stable at 26.65 [IQR: 22.48–30.63] before and 26.10 [IQR: 22.50–30.42] after ($p = 0.411$). Healthcare costs increased significantly, from 17,219 [IQR: 7,415.75–29,599.00] to 21,980 [IQR: 11,797.50–37,779.00] ($p < 0.001$). In-person visits to primary care physicians declined significantly from 7.00 [IQR: 3.00–12.00] to 5.00 [IQR: 2.00–11.00] ($p < 0.001$), while general medical practitioner visits showed a modest decrease ($p = 0.029$). Endocrinologist visits remained largely unchanged, with a median of 2.00 [IQR: 0.00–3.00] both before and after the intervention ($p = 0.063$). However, remote visits saw show a marked increase. Remote primary care doctor physicians visits rose significantly, from 2.00 [IQR: 0.00–6.00] before to 6.00 [IQR: 2.00–11.00] after the intervention ($p < 0.001$), while remote visits to general medical practitioners doubled, increasing from 4.00 [IQR: 1.00–8.00] before to 10.00 [IQR: 5.00–15.00] after the intervention ($p < 0.001$).

Figure 1 illustrates the changes in HbA1C levels and annual healthcare costs before and after the intervention. While the HbA1C levels showed a slight decrease after the intervention, from a median of 7.60 to 7.30, this reduction was not statistically significant, consistent with the results described in Table 3.

In contrast, annual healthcare costs displayed a noticeable increase post-intervention. The median cost rose from 15,944 ILS before the intervention to 23,117 ILSafterward, though this change was also not statistically significant. Overall, Fig. 1 visually reinforces the trends of stable HbA1C levels and rising healthcare costs following the intervention.

Figure 2 shows the correlation between HbA1c levels and medical factors before and after the intervention. The data suggests a moderate relationship between HbA1c and general medical factors, both before and after the intervention. However, no significant changes in the strength of these correlations were observed following

Table 3 Baseline characteristics by year with distribute by intervention

	Before intervention						After intervention					
	Overall	**2019**	**2020**	**2021**	**p value**	**p trend**	**Overall**	**2020**	**2021**	**2022**	**p value**	**p trend**
n	810	452	228	130			998	224	322	452		
BMI (median [IQR])	26.60 [21.92, 31.10]	26.65 [22.48, 30.63]	26.55 [21.20, 31.22]	26.60 [20.97, 31.32]	0.884	0.622	26.20 [22.80, 30.20]	26.30 [23.40, 29.72]	26.25 [23.02, 30.10]	26.10 [22.50, 30.42]	0.880	0.612
HbA1C (median [IQR])	7.60 [6.80, 8.50]	7.60 [6.80, 8.50]	7.60 [6.70, 8.50]	7.50 [7.00, 8.80]	0.376	0.464	7.30 [6.60, 8.20]	7.40 [6.50, 8.20]	7.30 [6.60, 8.20]	7.30 [6.60, 8.10]	0.861	0.641
Microalbuminuria (%)	5 (0.6)	5 (1.1)	0 (0.0)	0 (0.0)	NaN	0.071	11 (1.1)	2 (0.9)	3 (0.9)	6 (1.3)	NaN	0.569
Annual cost (median [IQR])	15944.00 [6955.50, 28667.25]	17219.00 [7415.75, 29599.00]	15161.00 [6610.00, 27964.00]	13915.00 [6790.00, 26725.00]	0.435	0.216	23117.00 [11835.00, 37989.00]	26164.00 [12429.25, 37685.25]	23803.00 [11446.50, 38492.25]	21980.00 [11797.50, 37779.00]	0.625	0.356
Frontal visit - Family doctor (median [IQR])	6.00 [2.00, 12.00]	7.00 [3.00, 12.00]	5.00 [2.00, 11.00]	5.00 [2.00, 11.00]	0.013	0.005	6.00 [2.00, 11.00]	7.00 [2.00, 12.00]	5.00 [2.00, 10.00]	5.00 [2.00, 11.00]	0.084	0.212
Frontal visit - General medical factor (median [IQR])	21.00 [12.00, 35.00]	24.00 [13.00, 36.00]	19.00 [10.00, 34.00]	19.00 [10.25, 36.25]	0.028	0.02	22.00 [14.00, 36.00]	24.00 [16.00, 45.00]	22.00 [14.00, 36.00]	20.00 [13.00, 33.25]	0.002	< 0.001
Endocrinologist (median [IQR])	2.00 [0.00, 3.00]	2.00 [0.00, 3.00]	1.50 [0.00, 3.00]	1.00 [0.00, 3.00]	0.837	0.575	2.00 [1.00, 4.00]	3.00 [2.00, 4.00]	2.00 [1.00, 4.00]	2.00 [0.00, 3.00]	< 0.001	< 0.001
Remote visit - Family doctor (median [IQR])	3.00 [0.00, 8.00]	2.00 [0.00, 6.00]	5.00 [1.00, 10.00]	5.00 [1.00, 9.00]	< 0.001	< 0.001	6.00 [2.00, 11.00]	6.00 [2.00, 12.00]	6.00 [1.00, 11.00]	6.00 [2.00, 11.00]	0.926	0.884
Remote visit - General medical factor (median [IQR])	5.00 [2.00, 10.00]	4.00 [1.00, 8.00]	7.00 [3.00, 13.25]	8.00 [3.25, 13.00]	< 0.001	< 0.001	10.00 [5.00, 16.00]	11.00 [7.00, 18.25]	9.00 [5.00, 16.00]	10.00 [5.00, 15.00]	0.001	0.002

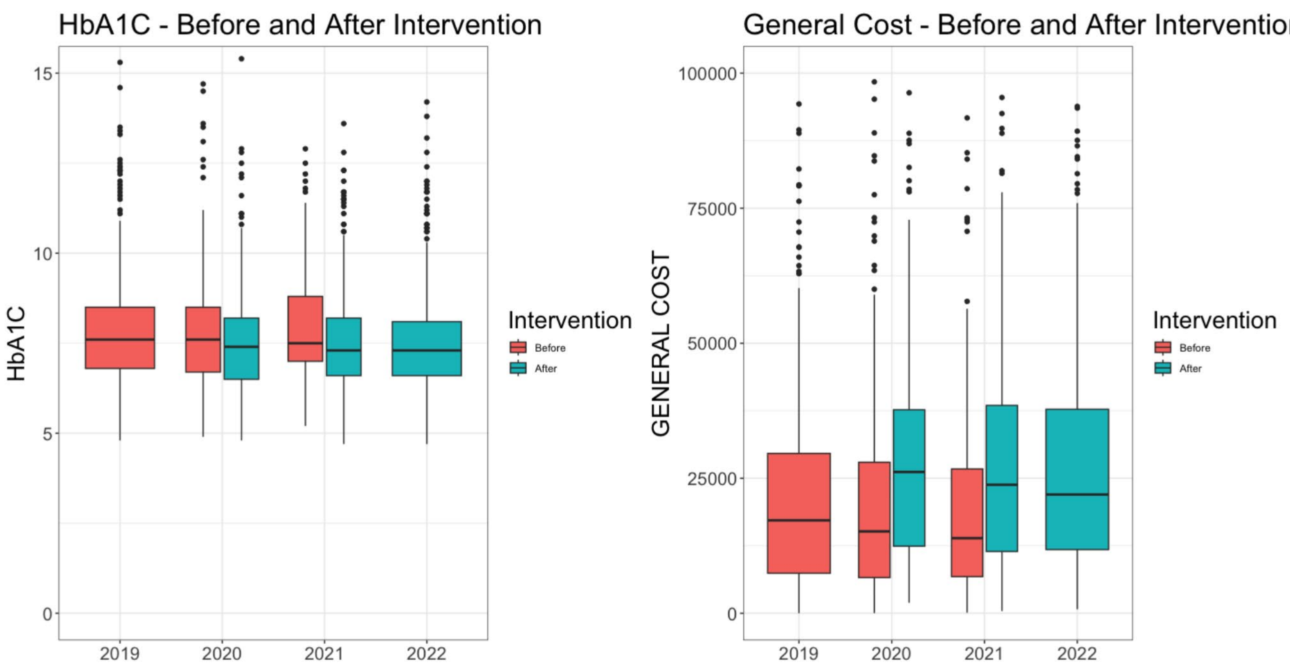

Fig. 1 HbA1C and cost before and after the intervention

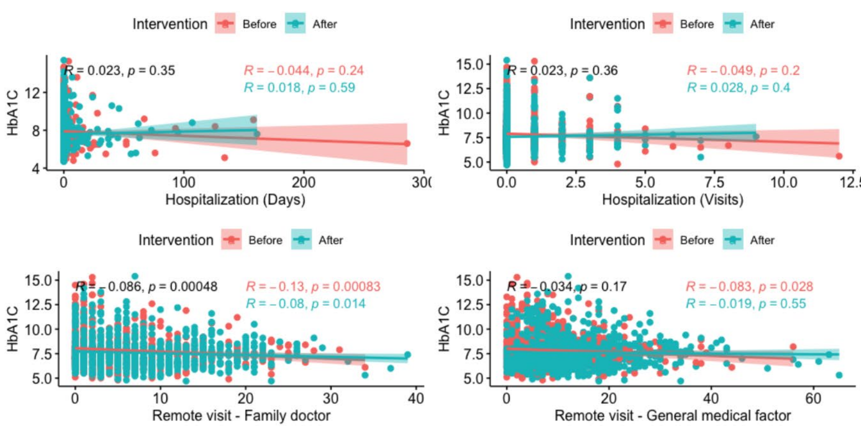

Fig. 2 Correlations between HbA1c and medical factor (before vs. after intervention)

the intervention, indicating that while medical factors remain associated with HbA1c levels, the intervention itself did not significantly alter this relationship.

The linear regression analysis for HbA1c levels before and after the intervention is summarized in Table 4. The results are presented for both unadjusted and adjusted models. For the time intervention (year), the unadjusted model showed a coefficient of 0.05 (95% CI: -0.07, 0.18; $p=0.42$) and the adjusted model showed 0.07 (95% CI: -0.06, 0.20; $p=0.30$). After the intervention, the unadjusted model indicated a significant decrease with a coefficient of -0.11 (95% CI: -0.19, -0.02; $p=0.02$), while the adjusted model showed a non-significant decrease with a coefficient of -0.05 (95% CI: -0.14, 0.05; $p=0.34$).

For age (per year), the coefficient was 0.01 (95% CI: -0.001, 0.02; $p=0.09$) in the unadjusted model and 0.01 (95% CI: -0.001, 0.02; $p=0.08$) in the adjusted model.

Regarding gender (female vs. male), the coefficient for females compared to males was 0.01 (95% CI: -0.29, 0.31; $p=0.96$) in the unadjusted model and −0.08 (95% CI: -0.34, 0.18; $p=0.56$) in the adjusted model.

For BMI, the coefficient was 0.004 (95% CI: -0.01, 0.01; $p=0.52$) in the unadjusted model and 0.002 (95% CI: -0.01, 0.01; $p=0.63$) in the adjusted model.

The remote visit to a primary care physicians showed a significant reduction in HbA1c levels with a coefficient of -0.06 (95% CI: -0.11, -0.01; $p=0.02$) in the unadjusted model and −0.04 (95% CI: -0.07, -0.01; $p=0.004$) in the adjusted model.

Table 4 Linear regression model for HBA1C (before vs. after intervention)

OLS regression model results				
	A1C			
	Unadjusted	**Adjusted**	**Unadjusted**	**Adjusted**
Time intervention (year)	0.05	0.07	-0.11*	-0.05
	(-0.07, 0.18)	(-0.06, 0.20)	(-0.19, -0.02)	(-0.14, 0.05)
	$p=0.42$	$p=0.30$	$p=0.02$	$p=0.34$
Age (per year)		0.01		0.01
		(-0.001, 0.02)		(-0.001, 0.02)
		$p=0.09$		$p=0.08$
Female (Female vs. Male)		0.01		-0.08
		(-0.29, 0.31)		(-0.34, 0.18)
		$p=0.96$		$p=0.56$
BMI		0.004		0.002
		(-0.01, 0.01)		(-0.01, 0.01)
		$p=0.52$		$p=0.63$
Remote visit - Family doctor		-0.06*		-0.04**
		(-0.11, -0.01)		(-0.07, -0.01)
		$p=0.02$		$p=0.004$
Frontal visit - Family doctor		-0.01		0.02*
		(-0.03, 0.01)		(0.002, 0.03)
		$p=0.33$		$p=0.04$
Remote visit - General medical factor		0.02		0.03*
		(-0.02, 0.06)		(0.004, 0.05)
		$p=0.25$		$p=0.03$
Hospitalization (Visit)		-0.04		-0.05
		(-0.19, 0.10)		(-0.19, 0.09)
		$p=0.55$		$p=0.48$
Hospitalization (Day)		-0.01		-0.01
		(-0.01, 0.001)		(-0.02, 0.01)
		$p=0.08$		$p=0.32$
Observations	710	700	937	929

Note:

$^{**}p<0.01$

$^{***}p<0.001$

For in-person visits to a primary care physicians, the coefficient was −0.01 (95% CI: -0.03, 0.01; $p=0.33$) in the unadjusted model and 0.02 (95% CI: 0.002, 0.03; $p=0.04$) in the adjusted model, indicating a significant increase in HbA1c levels in the adjusted model. The remote visit to a general medical factor showed a coefficient of 0.02 (95% CI: -0.02, 0.06; $p=0.25$) in the unadjusted model and 0.03 (95% CI: 0.004, 0.05; $p=0.03$) in the adjusted model, indicating a significant increase in HbA1c levels in the adjusted model. For hospitalization (visit), the coefficient was −0.04 (95% CI: -0.19, 0.10; $p=0.55$) in the unadjusted model and −0.05 (95% CI: -0.19, 0.09; $p=0.48$) in the adjusted model. For hospitalization (day), the coefficient was −0.01 (95% CI: -0.01, 0.001; $p=0.08$) in the unadjusted model and −0.01 (95% CI: -0.02, 0.01; $p=0.32$) in the adjusted model.

Discussion

The results of this study highlight several important findings regarding the impact of a diabetes specialist nurse intervention on clinical outcomes and healthcare utilization. A significant improvement in HbA1C levels was observed in the paired analysis of the same patients before and after the intervention, with a decrease from 7.60 to 7.30, indicating improved glycemic control. However, when analyzing annual trends across different patient groups (Table 3), no significant change was observed.

These findings align with previous research demonstrate the effectiveness of diabetes specialist nurse interventions in improving HbA1C levels.

For instance, a study by Qasim et al. (2019) found that diabetic counseling by specialist nurses significantly improved HbA1C levels among patients. One of the most notable findings was the significant increase in remote visits to primary care physicians and general medical practitioners following the intervention. This shift towards telemedicine reflects broader trends in healthcare, particularly accelerated by the COVID-19 pandemic. The increase in remote consultations may indicate improved access to care and patient engagement, which are critical components of effective diabetes management [9]. Conversely, in-person visits to primary care physicians and general medical practitioners primary care physicians showed a slight decline, although these changes were not statistically significant [10]. This suggests that while remote consultations increased, they did not completely replace in-person visits, highlighting the complementary role of telemedicine in diabetes care. The intervention did not significantly alter BMI values, which remained stable throughout the study period. This finding aligns with previous research indicating that short-term interventions may not substantially impact BMI in patients with diabetes [9]. Notably, this stability in BMI was observed despite the aging of the cohort, with the median age increasing from 58 years in 2019 to 62 years in 2022. This suggests that the intervention helped maintain BMI levels even as patients aged.

The median number of endocrinologist visits remained unchanged before and after the intervention, indicating that the specialist nurse intervention did not significantly impact the frequency of these visits. This stability suggests that while the intervention improved certain aspects of diabetes management, it did not reduce the need for specialist care. Previous research has also shown that diabetes specialist nurses play a crucial role in patient education and support, which can lead to better self-management and potentially reduce the need for frequent specialist visits [11].

The study also found a significant increase in annual healthcare costs per patient post-intervention. This rise in costs could be attributed to the increased frequency of remote consultations and possibly the implementation costs of the telemedicine infrastructure. While higher costs may be a concern, improved glycemic control and increased access to healthcare services could potentially lead to long-term cost savings by preventing diabetes-related complications. This is supported by evidence from other studies that have shown the cost-effectiveness of diabetes specialist nurse interventions in improving clinical outcomes and reducing hospital stays [9].

Limitation

This study has several limitations that should be considered when interpreting the results. First, the data were collected from a single cohort of patients over a specific period, which may limit the generalizability of the findings to other populations or settings. The demographic and regional characteristics of the study participants may differ from those in other areas, potentially affecting the applicability of the results.

Second, our study compared physician-led diabetes care (before the intervention) with diabetes specialist nurse-led telemedicine care (after the intervention). However, we did not differentiate between different nurse-led care models, such as care provided by NPs versus DSNs. Future research should explore whether differences exist within nurse-led diabetes management approaches.

Third, the study relied on self-reported data for some variables, which may be subject to recall bias or inaccuracies. This could affect the reliability of the reported healthcare utilization patterns and clinical outcomes.

Additionally, the study was conducted mostly during the COVID-19 pandemic, a period when social distancing measures significantly increased reliance on telemedicine. The observed rise in remote visits may have been partly influenced by pandemic-related healthcare shifts rather than solely due to the diabetes specialist nurse intervention. While the intervention played a key role in expanding remote diabetes care, it is difficult to fully isolate its impact from the broader system-wide adoption of telehealth during this period. Future studies should assess whether these trends persist beyond the pandemic to determine the long-term sustainability of remote diabetes management.

Finally, while annual healthcare costs increased significantly post-intervention, our analysis did not break down cost components (e.g., remote consultations, telemedicine infrastructure, medication adherence, and laboratory testing). As a result, it is difficult to attribute the increased costs solely to the intervention. A detailed cost analysis is necessary to assess whether the intervention is cost-effective in the long term.

Conclusion

The DSN intervention demonstrated a positive impact on glycemic control and healthcare utilization patterns among patients with diabetes. The intervention led to a statistically significant improvement in HbA1C levels ($p = 0.006$), indicating better glycemic management. Additionally, there was a notable increase in remote consultations during the study period, particularly in telemedicine visits provided by primary care physicians and general medical practitioners. This shift suggests improved access to care and a growing role for remote healthcare delivery.

However, BMI values and endocrinologist visit frequencies remained stable, suggesting that the intervention did not significantly alter these aspects of diabetes management.

The intervention was also associated with increased annual healthcare costs, emphasizing the need for a careful evaluation of its cost-effectiveness. While the short-term benefits are evident, further research is required to assess the long-term sustainability and financial implications of such interventions.

Overall, these findings underscore the potential benefits of integrating telemedicine into diabetes care and highlight the valuable role of diabetes specialist nurses in improving patient outcomes. Future studies should aim to differentiate the types of remote visits and further examine their impact on clinical and economic outcomes.

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Author contributions
SK- writing, research outline. SA, JC- Field of expertise, writing, OS- statistics, writing, MS- writing, statistics, research outline.

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Authorship: We confirm that all authors meet the following four criteria:
1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND.
2. Drafting the work or revising it critically for important intellectual content; and.
3. Final approval of the version to be published; AND.
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval
The study obtained approval from the university's ethics committee)MHS-0136 -23). All data collection procedures ensured anonymity. Nurses offered informed consent before participating, with the assurance of their right to withdraw from the study at any point and for any reason. Human subjects, including both practicing nurses and nursing students, were thoroughly briefed on the study's objectives and procedures. Participation was entirely voluntary, with each participant providing informed consent. This study was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki. A key aspect of the ethical framework was the emphasis on participants' autonomy. All subjects were clearly informed of their right to withdraw from the study at any time, without needing to justify their decision.

Consent for publication of identifying patient information
Not applicable.

Informed consent
to participate was obtained from all subjects.

Competing interests
The authors declare no competing interests.

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