Cureus
Part of SPRINGER NATURE

Open Access Review Article

Role of Family Medicine in Acute Diabetic Emergencies and Related Healthcare Utilization: A Systematic Review

Review began 10/13/2026
Review ended 10/28/2026
Published 10/29/2026

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DOI: 10.7759/cureus.118788

Majed Algaed [1], Omar Alanazi [1], Kadi Alfurayh [1], Layan Alzahrani [1], Hind Alabdullatif [1], Saqib Ali [2], Fahad Alruwaili [3], Najeeb Alshamy [4]

1. Family Medicine, First Health Cluster, Riyadh, SAU 2. Endocrinology and Diabetes, Endocrinology Unit & Centre of Excellence for Diabetes, King Salman Hospital, Ministry of Health, Riyadh, SAU 3. Family Medicine, Al-Jouf Health Cluster, Sakaka, SAU 4. Computer Sciences and Information Systems, Faculty of Computer Sciences and Information Systems, Thamar University, Dhamar, YEM

Corresponding author: Majed Algaed, majed.sa9819@gmail.com

Abstract

This systematic review synthesized evidence on whether structured family medicine-based or primary care diabetes management is associated with fewer acute diabetic emergencies and lower related healthcare utilization among adults with diabetes mellitus. The review was registered in the International Prospective Register of Systematic Reviews (CRD420261359851) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines. English-language primary studies published between 2015 and 2026 were identified through PubMed/MEDLINE, Web of Science, Scopus, and the Cochrane Central Register of Controlled Trials. Two reviewers independently screened eligible studies and extracted data. Risk of bias and certainty of evidence were assessed using the Grading of Recommendations Assessment, Development and Evaluation approach. Due to substantial heterogeneity, findings were synthesized narratively. Twenty studies from 13 countries or regions were included. Seven studies assessed acute diabetic outcomes, while 13 evaluated healthcare utilization. None reported diabetic ketoacidosis or hyperosmolar hyperglycemic state as individual endpoints. Most family medicine and primary care studies reported fewer acute glycemic events. Most utilization studies reported reductions in diabetes-related or potentially avoidable hospitalization or emergency care use. However, findings were inconsistent across studies. The certainty of evidence was very low for both outcome domains. Family medicine-based and primary care diabetes management may be associated with fewer acute events and lower utilization. However, the evidence is insufficient to establish that these models prevent specific diabetic emergencies, particularly diabetic ketoacidosis and hyperosmolar hyperglycemic state. Further studies using clearly defined emergency-specific outcomes are needed.

Categories: Family/General Practice, Emergency Medicine, Internal Medicine
Keywords: acute disease, diabetes mellitus, diabetic ketoacidosis, family medicine, hospitalization, hyperosmolar hyperglycemic state, hypoglycemia, primary health care, systematic review

Introduction And Background

Diabetes mellitus (DM) remains one of the most consequential global public health challenges. According to the 11th edition of the International Diabetes Federation (IDF) Diabetes Atlas, approximately 589 million adults aged 20-79 years had diabetes in 2024, with this number projected to reach 853 million by 2050 [1]. Similarly, the World Health Organization (WHO) reports rising prevalence, substantial premature mortality, and disproportionate burden in low- and middle-income countries [2]. In 2024, direct diabetes-related expenditure exceeded USD 1 trillion, and around 3.4 million adult deaths were attributable to diabetes [3].

The most clinically urgent manifestations of dysglycemia are diabetic ketoacidosis (DKA), hyperosmolar hyperglycemic state (HHS), and severe hypoglycemia. DKA is the leading acute hyperglycemic emergency worldwide and, although largely preventable, carries appreciable morbidity and mortality if treated late [4]. In plain terms, DKA is a hyperglycemic crisis in which insulin deficiency causes ketone accumulation and metabolic acidosis, whereas HHS is characterized by severe hyperglycemia and hyperosmolality with minimal ketosis; both usually develop over hours to days and require urgent hospital care [4,5]. Severe hypoglycemia is a low blood glucose event requiring external assistance [6]. Between 2004 and 2018 in Scotland, DKA event rates increased by approximately 6% per year, with widening socioeconomic disparities [7]. In England, sustained pressures on emergency services have been noted, with DKA admissions remaining above pre-pandemic baselines and increasing disproportionately among people with type 2 DM (T2DM) or newly diagnosed DM [8]. Likewise, US population data show rising emergency and inpatient utilization for hyperglycemic crises [9], and national-level inpatient analyses document increasing HHS hospitalizations alongside declining inpatient case fatality [5]. Severe hypoglycemia also imposes a substantial burden internationally. Hypoglycemia-related hospital admissions remain substantial in England [10]. Meanwhile, severe hospitalized hypoglycemia remains common in Scotland, with rates more than twofold higher in the most socioeconomically deprived groups [11]. Taken together, these emergencies

place sustained pressure on emergency and hospital services.

Timely recognition and appropriate outpatient management may help prevent many of these events. DKA often reflects modifiable antecedents such as insulin non-adherence and recurrent decompensation in patients with prior episodes [12]. Additionally, outpatient barriers-including fragmented follow-up and limited access to self-monitoring resources-may delay deterioration recognition before emergency presentation [13]. However, precipitating factors typically emerge outside hospital settings during intercurrent illness, treatment lapses, or delayed therapy adjustment; thus, prevention has increasingly relied on sustained community-based monitoring rather than reactive acute care alone.

Family medicine is well positioned to deliver that community-based role. WONCA Europe [14] defines general practice and family medicine as a person-centered discipline offering comprehensive, continuous care within patients' family and community context. Its competencies encompass biopsychosocial understanding, coordination across care levels, and responsibility for both prevention and treatment. Within this framework, family physicians provide ongoing glycemic oversight and hypoglycemia-risk assessment [6], alongside structured education, medication optimization, scheduled follow-up, and timely referral when specialized care is needed [15]. Currently, the effectiveness of such primary care-based organization in reducing acute emergencies as compared with specialist-led or unstructured usual care remains uncertain. Most primary care studies, however, evaluate heterogeneous teams, disease-management contracts, or incentive schemes without isolating the contribution of family physicians. Family medicine differs from generic primary care in its first-contact responsibility, continuity across episodes, and coordination of care over time [14]; evidence specific to family medicine is therefore needed before its role in acute emergency prevention can be judged.

While specialist-led care provides disease-specific expertise, primary care models emphasize continuity, coordination, and longitudinal monitoring [14]. However, available literature is largely indirect. Observational studies often report emergency department (ED) use, hospital admissions, or other utilization measures rather than directly measured acute DM emergency outcomes. In this review, direct acute outcomes are defined as DKA, HHS, severe hypoglycemia, or closely related glycemic-crisis measures, whereas healthcare utilization outcomes include ED visits, diabetes-related or potentially avoidable hospitalization, hospital bed-days, and other administrative utilization measures. The two domains are related but not interchangeable: a reduction in hospitalization does not by itself demonstrate that DKA or HHS was prevented. Higher care continuity has been associated with lower ED use in Taiwan [16]. In the United States, patients who consistently saw the same primary care physicians had 25%-50% fewer ED visits and hospitalizations [17]. Furthermore, completing general-practice DM processes was associated with 22%-26% lower emergency admissions in England [18].

Despite this plausible rationale, important questions remain. Theoretically, guideline frameworks and primary care cohort studies support prevention-oriented care; however, acute DM emergencies have rarely been examined as primary outcomes. Most of the published studies reported glycemic surrogates, chronic complications, or undifferentiated hospitalization. Intervention models are often labeled broadly as primary care or disease management, obscuring the distinct aspects of structured family medicine, while comparators seldom isolate family physician-led care from specialist-led alternatives. Given that DKA, HHS, and severe hypoglycemia differ from chronic complications in terms of pathophysiology and precipitants, this evidentiary gap limits both clinical inference and health-system planning. Therefore, this systematic review aimed to synthesize evidence on whether structured family medicine-based or primary care DM management is associated with fewer acute DM emergencies and related healthcare utilization among adults with type 1 DM (T1DM) or T2DM.

Review

Methods

Protocol and Registration

This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) on April 3, 2026 (registration number: CRD420261359851), and was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [19]. The registration was completed before data extraction. The protocol defined the review question, eligibility criteria, the two outcome domains, the risk-of-bias tools, and the narrative synthesis approach.

Eligibility Criteria

Eligibility criteria for selecting studies were defined using the Patient/Population, Intervention, Comparator/Control, and Outcome(s) (PICO) framework. This review considered family medicine within the broader organized primary care framework, including family physicians, general practitioners (GPs), and multidisciplinary primary care models delivering structured DM management. Studies were included according to the following criteria: were published as primary empirical studies in peer-reviewed journals;

included adults aged 18 years or older with T1DM or T2DM; investigated structured family medicine-based or primary care-based DM management; included a comparison group or comparative condition (e.g., specialist-led care, usual care, non-structured primary care, historical/pre-intervention controls, or different models or levels of primary care delivery); reported acute DM-related outcomes or healthcare utilization outcomes (e.g., DKA, HHS, severe hypoglycemia, ED visits, hospitalizations, and DM-related acute care utilization) as defined in each included study; were conducted in primary care, family medicine, or community-based healthcare settings; were published between 2015 and 2026; and reported a clearly defined follow-up period of at least one month (⩾4 weeks). Conversely, the exclusion criteria were as follows: focused exclusively on chronic DM complications without reporting acute events or healthcare utilization outcomes; included only pediatric populations (<18 years); were editorials, case reports, letters, conference abstracts, or expert opinions; were conducted exclusively in inpatient or intensive care unit settings; and were published in languages other than English.

Information Sources and Search Strategy

PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched for literature published between 2015 and 2026. The searches were executed on May 15, 2026 (PubMed/MEDLINE), May 22, 2026 (Scopus), June 3, 2026 (Web of Science), and June 8, 2026 (CENTRAL). The complete search strategies and the database-specific search dates are presented in Appendices A, B. The upper date limit of December 31, 2026 in the PubMed filter was the boundary of the date filter, not the date on which the search was executed. The strategies combined controlled vocabulary and free-text terms related to DM; family medicine, primary care, and general practice; structured DM management; and acute DM-related outcomes, including DKA, HHS, severe hypoglycemia, ED visits, hospitalization, and DM-related healthcare utilization. Furthermore, the reference lists of included studies and relevant systematic reviews were manually reviewed. Supplementary searches comprised backward citation tracking of all included studies and relevant systematic reviews and a targeted PubMed update on June 8, 2026 using the same search string; these searches identified 39 additional records. Retrieved records were exported from the databases and imported into Rayyan [20]. Additionally, duplicate records were removed through automated deduplication and manually verified.

Study Selection

Two reviewers independently screened study titles and abstracts against the pre-defined eligibility criteria. Potentially eligible reports were retrieved in full and further assessed for inclusion. During both screening stages, reasons for exclusion were recorded in Rayyan. Disagreements were resolved by discussion and, when necessary, by a third reviewer acting as adjudicator. Agreement between reviewers at each screening stage was summarized as percentage concordance before consensus. The PRISMA 2020 flow diagram was used for summarizing the study selection process, as presented in the Results section.

Data Collection

A pilot-tested standardized form aligned with the review PICO was used for extracting the following data: author, year, country, study design, setting, sample size, DM type, population characteristics, intervention or exposure, comparator, follow-up duration, outcome definitions, and results relevant to acute DM emergencies and related healthcare utilization. No data were imputed. Where a report did not provide an effect estimate, confidence interval (CI), or P-value, only the available information was extracted.

If more than one publication referred to the same study, data were extracted from the most complete report and supplemented from related publications as needed. If studies reported more than one comparator, data for all relevant comparisons were extracted.

Risk-of-Bias Assessment

Two reviewers independently assessed risk of bias using study-design-appropriate tools. Randomized controlled trials were rated as low risk, some concerns, or high risk of bias according to the Cochrane Risk of Bias 2 tool (RoB 2) [21]. Non-randomized interventional studies other than interrupted time series (ITS) designs were rated as low, moderate, serious, or critical risk of bias according to the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool [22]. Cohort and observational studies evaluating associations rather than intervention effects were assessed using the star-based scoring system of the Newcastle-Ottawa Scale [23]. Two ITS studies included in the review were assessed using the Cochrane Effective Practice and Organization of Care risk-of-bias criteria adapted for ITS designs [24], with attention to comparator series, secular trends, autocorrelation, and outcome ascertainment. No study was excluded solely according to risk of bias; judgments were used to inform interpretation of the findings. Study-level judgments and the principal domain concerns are reported in the Results section.

Data Synthesis

Clinical and methodological heterogeneity was substantial across study designs, interventions, comparators,

and outcome definitions; thus, findings were synthesized narratively rather than pooled quantitatively. Quantitative pooling was not undertaken because the studies differed in design (randomized trials, ITS, controlled before-after studies, and claims cohorts), intervention content, comparators, follow-up, outcome definitions, and effect measures (odds ratios, hazard ratios, incidence rate ratios, risk differences, and difference-in-differences), and because several cohorts drew on overlapping data sources; a pooled estimate would therefore have combined non-comparable estimands. Through a structured narrative synthesis [25], evidence was organized within a framework by outcome focus, study design, and geographic setting, and direct acute endpoints were distinguished from broader utilization outcomes. Given no quantitative pooling, the Synthesis Without Meta-analysis (SWiM) reporting guideline was applied for narrative synthesis reporting [26]. Study characteristics and published effect estimates were tabulated and grouped by outcome domain and intervention stratum. Studies were grouped first by outcome domain and then by intervention type (family physician-led care, structured family medicine programs, broader primary care programs, and continuity or exposure models). The direction of association was classified as favorable (↓), unfavorable (↑), or no significant or clinically meaningful difference (↔) on the basis of the published estimate, its CI, and, where available, the absolute effect; statistical significance was not equated with clinical importance. Composite endpoints were retained within the acute domain only and were not interpreted as estimates for any individual emergency; no study reporting only a composite endpoint was counted as reporting DKA or HHS separately. Possible overlap was defined as the same institution, region, administrative database, or recruitment period, with a plausible possibility that individual participants contributed to more than one report. Two pairs met this definition (Seidu et al. [27] and Brady et al. [28]; Karimova et al. [29] and Leutgeb et al. [30]); overlapping reports were not combined, and each member of both pairs was excluded individually in sensitivity analyses. Sensitivity analyses also restricted interpretation to family-medicine-core studies and separated Ramadan-specific interventions; these analyses tested the robustness of the narrative synthesis rather than generating pre-specified effect estimates.

Certainty of Evidence

Certainty of evidence across outcome domains was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [31,32]. Given that findings were not pooled quantitatively, certainty ratings were applied not to individual study estimates but to the overall body of evidence for each outcome domain. Two reviewers independently considered the GRADE domains-risk of bias, inconsistency, indirectness, imprecision, and publication bias-and resolved disagreements by discussion, with a third reviewer when necessary. Certainty started at low for the utilization domain, which was entirely observational. The acute domain combined randomized and non-randomized designs, so it was not assigned a single design-based starting level. Instead, two design-specific bodies of evidence were rated in parallel: the four randomized trials (starting high) and the three non-randomized studies (starting low), each assessed across the five GRADE domains [31,32]. Both ratings are reported separately: the randomized body was downgraded for risk of bias, inconsistency, and imprecision (very low), and the non-randomized body for risk of bias, inconsistency, and indirectness (very low). Because both bodies were rated very low, the single overall statement for the acute domain is very low; the two ratings were not averaged, and no lower-of-two rule was applied. This approach does not pool the designs and does not claim that GRADE assigns one starting level to mixed evidence. Moreover, no meta-analysis was performed; hence, publication bias was not formally tested with funnel plots. Certainty was rated separately for the two outcome domains. Reviewers could downgrade by one or two levels for risk of bias, inconsistency, indirectness, imprecision, or publication bias and could upgrade for a large effect, dose-response, or plausible confounding; no domain met the criteria for upgrading, and no domain was upgraded. The starting level, downgrades, and net rating for each domain are reported with the findings.

Results

Study Selection

A total of 5,986 records were identified, with 1,547 from PubMed/MEDLINE, 1,136 from Scopus, 3,236 from Web of Science, 28 from Cochrane CENTRAL, and 39 from supplementary searches of reference lists and targeted PubMed updates. After removal of 56 duplicates, 5,930 reports were screened by title and abstract (Figure *1*).

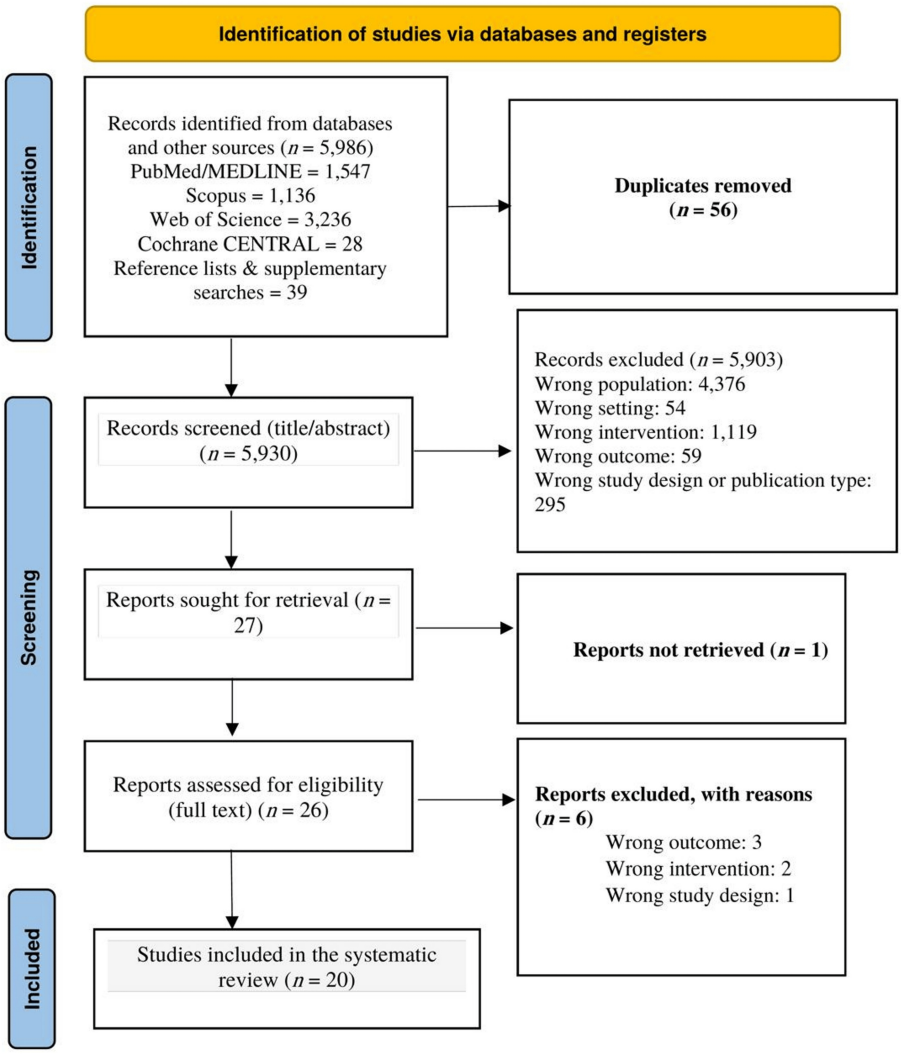


FIGURE 1: PRISMA 2020 flow diagram of study selection

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Agreement before consensus was 98.8% at title and abstract screening (71 conflicts among 5,930 records) and 96.2% at full-text assessment (one conflict among 26 reports) (Appendix C). Of the 5,930 screened reports, 5,903 were excluded at the title and abstract screening stage, with ineligible population, intervention, and study design as the main reasons. Subsequently, 27 remained, although full text could not be obtained for one report. Of the 26 remaining reports subjected to full-text assessment, six were excluded for the following reasons: wrong outcome in three, wrong intervention in two, and ineligible study design (protocol without published primary results) in one. Ultimately, 20 studies were included in the final narrative synthesis (Figure *1*).

Study Characteristics

Table *1* summarizes the included studies [27-30,33-48], with detailed characteristics provided in Appendix D. The 20 studies were conducted in 13 countries or regions across Asia, Europe, North America, and Oceania. Sample sizes ranged from 60 adults [33] to 1,817,682 adults with T2DM [34] among diabetes-specific cohorts, whereas one claims analysis included approximately 1.93 million insured adults from the general population [30], and follow-up ranged from one month to 12 years.

Study	Country	Design	Population	Intervention/exposure	Comparator	Outcomes	Follow-up
Chou et al. [36]	Taiwan	Retrospective cohort	206,819 adults with newly diagnosed T2DM	Family physician-led care	Endocrinologist- or internist-led care	Composite acute complications (DKA/HHS/hypoglycemia combined)	24 months

Tourkmani et al. [37]	Saudi Arabia	Non-randomized intervention study	262 adults with T2DM	Ramadan-focused family medicine program	Standard clinical care	Hypoglycemia score	~6 months
Mohamed et al. [33]	UAE	RCT	60 adults with T2DM	PRINTED 1 pre-Ramadan education	Usual care	Hypoglycemia frequency	~1 month
Gilliam et al. [35]	USA	RCT	191 high-risk adults with T2DM	Pharmacist-led HOAP outreach	Usual primary care	Severe hypoglycemia (ED/inpatient)	6 months
Karimova et al. [29]	Germany	Retrospective cohort	217,964 adults with diabetes	GP-centered healthcare (HZV)	Usual GP care	Hypoglycemia; complications	10 years
Zhang et al. [48]	Australia	Prospective non-randomized controlled study	327 adults with complex T2DM	Integrated primary-secondary care	Hospital specialist clinic	PAH	24 months
Wong et al. [47]	Hong Kong	Matched cohort	24,250 adults with T2DM in primary care	Patient Empowerment Program	No program	All-cause hospitalization; ED visits	Median 30.5 months
Goff et al. [43]	USA	Controlled before-after	319 adults with T2DM (Medicaid)	Buena Salud enhanced primary care	Usual care (same center)	All-cause hospitalization; ED visits	12-15 months
Fortmann et al. [41]	USA	Quasi-experimental	475 adults with T1DM or T2DM	Cardiometabolic care team	Usual primary care	All-cause hospitalization; ED visits	12 months
Moorin et al. [46]	Australia	Linked administrative study	27,409 adults with diabetes (NSW)	High GP contact regularity	Lower regularity quintiles	Unplanned diabetes-related hospitalization and ED visits	Not applicable (cross-sectional)
Georgescu et al. [42]	France	Population cohort	25,293 adults with diabetes	10-14 GP visits/year	Fewer GP visits	PAH (incl. short-term diabetes complications)	Outcome assessment after 1 year
Höglinger et al. [45]	Switzerland	Prospective observational	538 vs. 5,050 adults with diabetes (DMP vs. controls)	Primary care disease-management program	Usual primary care	All-cause hospitalization	24 months
Lee and Kim [34]	South Korea	Retrospective cohort	1,817,682 adults with T2DM	Primary Care CDMP	Non-participants	PAH	≤4 years
Leutgeb et al. [30]	Germany	Retrospective cohort	~1.93 million insured adults (general insured population, not restricted to diabetes)	GP-centered healthcare	Regular primary care	PAH; all-cause hospitalization	12 years
Jia et al. [39]	China	Cluster RCT	19,546 adults with T2DM (864 clusters)	ROADMAP mHealth model	Usual primary care	Hypoglycemia	12 months
Ha et al. [44]	Australia	Retrospective cohort	21,965 adults ≥ 45 y with diabetes	GP cover index (longitudinal)	Perfect GP cover	Unplanned diabetes hospitalization	3 years
Carter et al. [38]	Canada	Interrupted time series	Adults with T1DM or T2DM (Quebec cohort)	Family Medicine Groups reform	Pre-reform trend	ED visits for acute diabetes complications	12 years
Seidu et al. [27]	UK	Controlled before-after study	Adults with diabetes from 8 enhanced and 8 core primary care practices	Enhanced primary care diabetes service	Integrated specialist-community service	Non-elective hospital bed-days	12 months
Brady et al. [28]	UK	Interrupted time series	Adults with T2DM from a regional population	Transformation model	Pre-implementation trend	T2DM-related hospital bed-days	Multiyear
Ibrahim et al. [40]	Multinational	Open-label RCT	452 adults with T2DM	Pre-Ramadan structured primary care education	Usual care	Severe hypoglycemia; hypoglycemic episodes	Ramadan cycle

TABLE 1: Characteristics of the included studies (n = 20)

RCT: randomized controlled trial; DKA: diabetic ketoacidosis; HHS: hyperosmolar hyperglycemic state; ED: emergency department; GP: general practitioner; PAH: potentially avoidable hospitalization; HZV: Hausarztzentrierte Versorgung; HOAP: Hypoglycemia on a Page; DMP: disease management program; CDMP: Chronic Disease Management Program; NSW: New South Wales; T2DM: type 2 diabetes mellitus; T1DM: type 1 diabetes mellitus

Study designs included four randomized trials (two individually randomized controlled trials, one multinational open-label trial, and one cluster-randomized trial), six non-randomized intervention or quasi-experimental studies, eight observational cohort or linked administrative studies, and two population-based ITS analyses (Table *1*). Interventions spanned structured family medicine education, Ramadan-focused primary care programs, disease-management programs or GP-centered care models, GP contact regularity or continuity, integrated care models, mHealth-supported care, and comparisons between family physician-led care versus other physician-led care models. Additionally, Gilliam et al. [35] evaluated pharmacist-led outreach within collaborative primary care teams rather than a family physician-led intervention.

On the basis of primary reported outcomes, seven studies reported direct acute endpoints, whereas 13 reported healthcare utilization outcomes (Table *1*). Furthermore, 11 studies were restricted to T2DM, while nine included both T1DM and T2DM or mixed or unspecified DM populations. Four studies were classified as family medicine-core studies because the intervention was explicitly family physician-led or a family medicine organizational reform: Chou et al. [36] (family physician-led care), Mohamed et al. [33] (family physician-delivered education), Tourkmani et al. [37] (family medicine center program), and Carter et al. [38] (Family Medicine Groups reform). Ibrahim et al. [40] was not classified as core because the report describes a multinational primary care-delivered program without specifying family physician leadership; it was retained in the broader primary care stratum. Gilliam et al. [35] was also not core because the intervention was pharmacist-led. The full classification is presented in Appendix E. Potential overlap of populations or data sources was noted in two study pairs: Seidu et al. [27] and Brady et al. [28] (Leicester), and Karimova et al. [29] and Leutgeb et al. [30] (German claims). These overlaps reflected shared settings or administrative data sources rather than confirmed individual-level duplication; both pairs were examined separately and in sensitivity analyses.

Risk of Bias in Included Studies

Tables *2*, *3* present the distribution of risk-of-bias judgments according to assessment tool and the study-level risk-of-bias assessments, respectively. Findings were reported descriptively and were not combined quantitatively across instruments.

Assessment category	n (%)	Studies
Low (RoB 2)	1 (5)	Gilliam et al. [35]
Some concerns (RoB 2/EPOC ITS)	5 (25)	Mohamed et al. [33]; Ibrahim et al. [40]; Jia et al. [39]; Carter et al. [38]; Brady et al. [28]
Moderate (ROBINS-I)	3 (15)	Zhang et al. [48]; Fortmann et al. [41]; Höglinger et al. [45]
Serious (ROBINS-I)	3 (15)	Tourkmani et al. [37]; Goff et al. [43]; Seidu et al. [27]
NOS score band (7-8/9 stars)	8 (40)	Chou et al. [36]; Karimova et al. [29]; Wong et al. [47]; Moorin et al. [46]; Georgescu et al. [42]; Lee and Kim [34]; Leutgeb et al. [30]; Ha et al. [44]

TABLE 2: Distribution of risk-of-bias assessments according to assessment tool (n = 20)

RoB 2: Cochrane Risk of Bias 2 tool; EPOC ITS: Cochrane Effective Practice and Organization of Care criteria for interrupted time series; ROBINS-I: Risk Of Bias In Non-randomized Studies of Interventions; NOS: Newcastle-Ottawa Scale

Study	Design	Assessment tool	Overall assessment	Principal domain concerns
Mohamed et al. [33]	RCT	RoB 2	Some concerns	Randomization process (limited reporting of sequence generation and allocation concealment); deviations from intended interventions
Gilliam et al. [35]	RCT	RoB 2	Low	Overall low risk of bias; all RoB 2 domains were judged as low risk
Ibrahim et al. [40]	Open-label RCT	RoB 2	Some concerns	Open-label delivery; missing outcome data because of incomplete follow-up

Jia et al. [39]	Cluster RCT	RoB 2	Some concerns	Cluster allocation and potential deviations from intended interventions because of no blinding
Tourkmani et al. [37]	Non-randomized intervention study	ROBINS-I	Serious	Confounding; participant selection
Zhang et al. [48]	Prospective non-randomized controlled study	ROBINS-I	Moderate	Confounding; selection of participants into integrated care
Goff et al. [43]	Controlled before-after	ROBINS-I	Serious	Confounding; participant selection
Fortmann et al. [41]	Quasi-experimental	ROBINS-I	Moderate	Confounding; participant selection (clinic-level allocation)
Höglinger et al. [45]	Prospective observational	ROBINS-I	Moderate	Confounding; selection into DMP
Seidu et al. [27]	Controlled before-after study	ROBINS-I	Serious	Confounding; participant selection; short follow-up
Chou et al. [36]	Retrospective cohort	NOS	8/9 stars	Representativeness of the exposed cohort; claims coding; physician self-selection
Karimova et al. [29]	Retrospective cohort	NOS	7/9 stars	Voluntary HZV enrollment; claims ascertainment
Wong et al. [47]	Matched cohort	NOS	8/9 stars	Residual confounding after propensity matching
Moorin et al. [46]	Linked administrative study	NOS	7/9 stars	Study design limitations; self-selection into GP contact patterns
Georgescu et al. [42]	Population cohort	NOS	8/9 stars	Exposure-outcome lag; residual confounding in claims data
Lee and Kim [34]	Retrospective cohort	NOS	7/9 stars	Self-selection into CDMP; claims data
Leutgeb et al. [30]	Retrospective cohort	NOS	7/9 stars	Voluntary GP-centered healthcare contract; claims data
Ha et al. [44]	Retrospective cohort	NOS	7/9 stars	Self-selection into GP cover; observational linkage cohort
Carter et al. [38]	ITS	Cochrane EPOC ITS criteria	Some concerns	Concurrent health-system changes; autocorrelation considered in the analysis
Brady et al. [28]	ITS	Cochrane EPOC ITS criteria	Some concerns	Single-region implementation; concurrent policy changes possible

TABLE 3: Risk-of-bias summary of the included studies (n = 20)

RCT: randomized controlled trial; ITS: interrupted time series; RoB 2: Cochrane Risk of Bias 2 tool; ROBINS-I: Risk Of Bias In Non-randomized Studies of Interventions; NOS: Newcastle-Ottawa Scale; EPOC: Effective Practice and Organization of Care; HZV: Hausarztzentrierte Versorgung; DMP: disease management program; CDMP: Chronic Disease Management Program; GP: general practitioner

Findings by Outcome

Findings were synthesized narratively according to outcome domain, with effect estimates reported as published and with 95% CIs or P-values where the source publication provided them; no estimate was imputed. No secondary outcomes were synthesized because no eligible studies reported them as review-relevant endpoints.

Direct Acute DM Emergencies and Glycemic Crises

Seven included studies measured direct acute or glycemic-crisis outcomes [29,33,35-37,39,40]. These studies comprised four randomized trials (including one multinational open-label trial), one non-randomized controlled study, and two retrospective cohorts. No included study reported DKA or HHS as an individual endpoint; Chou et al. [36] reported both only within a composite of DKA, HHS, or hypoglycemia.

Among the four trials, Gilliam et al. [35] reported zero versus 5.3% hypoglycemia-related ED or inpatient events (risk difference, −5.3%; 95% CI, −11.8% to −1.3%). Mohamed et al. [33] found that following structured pre-Ramadan education, hypoglycemia frequency during Ramadan declined from 40% to 16.7%, whereas controls remained at 33.3% (P = 0.003). Ibrahim et al. [40] showed that the severe hypoglycemia rate was 0.9% with pre-Ramadan structured primary care education versus 4.1% with usual care (odds ratio, 0.2; 95% CI, 0.1-0.8). Conversely, Jia et al. [39] observed no statistically significant between-group difference in hypoglycemia episodes.

In cohort and non-randomized designs, Chou et al. [36] reported that, compared with family physician-led care, endocrinologist-led care was associated with a higher risk of acute complications (DKA, HHS, or hypoglycemia) (1.29% vs. 2.05%; subdistribution hazard ratio for endocrinologist-led care, 1.57; 95% CI, 1.38-1.78). Similarly, internist-led care was associated with a higher risk of the same acute complications as compared with family physician-led care (1.42% vs. 2.35%; subdistribution hazard ratio for internist-led care, 1.26; 95% CI, 1.08-1.47). Post-Ramadan hypoglycemia symptom scores were more reduced in individuals who received a Ramadan-focused family medicine program than in individuals receiving standard care (−61.7% vs. −33.8%, P < 0.001) [37]. Using administrative claims, Karimova et al. [29] reported a statistically significant yet small increase in coded hypoglycemia under GP-centered healthcare (hazard ratio, 1.012; 95% CI, 1.002-1.022; P = 0.019).

At the population level, Carter et al. [38] reported that, nine years after the Family Medicine Groups reform, the estimated rate of avoidable ED visits for acute diabetes-related complications was 2.12 (95% CI, −2.94 to −1.29) visits per 10,000 diabetic patients per week lower than the rate predicted from the pre-reform trend in urban regions, and 2.25 (95% CI, −3.64 to −0.85) lower in rural regions. The post-reform slope corresponded to a rate ratio of 0.99 (95% CI, 0.98-0.99) per week, approximately a 1% reduction per week. The immediate level change was not statistically significant in urban regions (rate ratio, 1.04; 95% CI, 0.98-1.10) but showed a significant early increase in rural regions (rate ratio, 1.12; 95% CI, 1.04-1.20); the change-in-trend terms were not significant in either region (rate ratio, 0.99; 95% CI, 0.99-1.00). The authors noted that the estimated and predicted rates diverged gradually rather than abruptly. This finding is therefore classified as a qualified favorable association: statistically significant in relative and absolute terms by year 9, with a significant early rural increase and uncertainty about the reform-specific effect (Table 4).

Study	Diabetes type	Primary outcome	Effect estimate	Direction of association
Direct acute diabetic emergencies and glycemic crises (n = 7)				
Chou et al. [36]	T2DM	Composite DKA/HHS/hypoglycemia	FM 1.29% vs. endo 2.05%; FM 1.42% vs. IM 2.35%; sHR 1.57 (95% CI, 1.38-1.78) and 1.26 (95% CI, 1.08-1.47), FM as reference	↓
Tourkmani et al. [37]	T2DM	Hypoglycemia symptom score	Post-Ramadan reduction −61.7% vs. −33.8% (P < 0.001)	↓
Mohamed et al. [33]	T2DM	Hypoglycemia frequency (Ramadan)	40% → 16.7% vs. unchanged 33.3% (P = 0.003)	↓
Gilliam et al. [35]	T2DM	Severe hypoglycemia (ED/inpatient)	0% vs. 5.3%; RD, −5.3% (95% CI, −11.8 to −1.3%)	↓
Ibrahim et al. [40]	T2DM	Severe hypoglycemia (Ramadan)	0.9% vs. 4.1%; OR, 0.2 (95% CI, 0.1-0.8)	↓
Karimova et al. [29]	T1/T2	Claims-defined hypoglycemia	HR, 1.012 (95% CI, 1.002-1.022; P = 0.019)	↑
Jia et al. [39]	T2DM	Hypoglycemia episodes	No significant between-group difference (effect estimate not reported)	↔
Healthcare utilization outcomes (n = 13)				
Zhang et al. [48]	T2DM	PAH (diabetes-related principal diagnosis)	IRR, 0.53 (95% CI, 0.29-0.96)	↓
Wong et al. [47]	T2DM	All-cause hospitalization; ED visits	HR, 0.879 and 0.901; IRR, 0.854 and 0.903 (P < 0.001 for all)	↓

Moorin et al. [46]	Mixed	Unplanned diabetes-related hospitalization and ED visits	19.9% vs. 23.5% (highest vs. lowest GP regularity quintile; no CI reported)	↓
Goff et al. [43]	T2DM	All-cause hospitalization (unplanned)	DID, −11.7% (P = 0.11 adjusted)	↔
Fortmann et al. [41]	T1/T2	ED visits; all-cause hospitalization	Intervention vs. control: 0.04 vs. 0.17 ED visits (P = 0.002); 0.05 vs. 0.19 hospitalizations per patient (P = 0.004)	↓
Georgescu et al. [42]	Mixed	PAH (incl. short-term diabetes complications)	10-14 GP visits vs. fewer: aHR, 0.49 (P < 0.001)	↓
Höglinger et al. [45]	T1/T2	All-cause hospitalization (1 y)	DID, −5.7 pp (95% CI, −11.0 to −0.7)	↓
Lee and Kim [34]	T2DM	PAH (preventable diabetes-related)	HR, 0.729 (95% CI, 0.696-0.764)	↓
Leutgeb et al. [30]	Mixed	PAH; all-cause hospitalization	−2.46 PAH and −8.61% all-cause hospitalization per 100 individuals (2022; no CI reported)	↓
Ha et al. [44]	Mixed	Unplanned diabetes hospitalization (lower vs. perfect GP cover)	Lower GP cover vs. perfect cover: IRR, 1.7-3.2 (no CI reported), indicating higher hospitalization with reduced continuity	↓ (protective association with higher GP cover)
Seidu et al. [27]	Mixed	Non-elective hospital bed-days	+2.20 per 100 patients (P = 0.14)	↔
Brady et al. [28]	T2DM	T2DM-related hospital bed-days	Slope change P = 0.04 (post vs. pre)	↓
Carter et al. [38]	T1/T2	ED visits for acute diabetes complications	Post-reform slope RR, 0.99 (95% CI, 0.98-0.99) per week; estimated vs. predicted absolute change at 9 y, −2.12 (95% CI, −2.94 to −1.29) urban and −2.25 (95% CI, −3.64 to −0.85) rural visits per 10,000/week; immediate level change non-significant in urban regions but a significant early increase in rural regions (RR 1.12; 95% CI, 1.04-1.20); change-in-trend terms not significant	↓ (qualified)

TABLE 4: Primary outcome effect estimates by outcome domain (n = 20)

Direction of association: ↓: favorable direction (lower acute events or utilization); ↑: unfavorable direction; ↔: no significant or clinically meaningful difference; ↓ (qualified): statistically significant estimate with an important caveat about the estimand, the absolute magnitude, or the reform-specific effect. Where a source publication did not report a 95% CI or P-value, the available estimate is shown without imputation.

FM: family medicine; endo: endocrinology; IM: internal medicine; sHR: subdistribution hazard ratio; RD: risk difference; OR: odds ratio; HR: hazard ratio; IRR: incidence rate ratio; aHR: adjusted hazard ratio; DID: difference-in-differences; pp: percentage points; PAH: potentially avoidable hospitalization; ED: emergency department; GP: general practitioner; T2DM: type 2 diabetes mellitus; DKA: diabetic ketoacidosis; HHS: hyperosmolar hyperglycemic state; CI: confidence interval; RR: relative risk

Healthcare Utilization Outcomes

Moreover, 13 included studies measured healthcare utilization outcomes [27,28,30,34,38,41-48]. In national and regional claims cohorts, Lee and Kim [34], Leutgeb et al. [30], and Georgescu et al. [42] reported reductions in preventable or DM-related unplanned hospitalization, while Ha et al. [44] reported that lower GP cover was associated with higher hospitalization rates compared with sufficient GP cover (Table *4*). Wong et al. [47], Moorin et al. [46], and Höglinger et al. [45] reported reductions in hospitalization or emergency utilization endpoints (Table *4*).

Among interventional and practice-level studies, Zhang et al. [48] and Fortmann et al. [41] reported that potentially avoidable hospitalization or combined emergency and inpatient utilization were reduced, while Goff et al. [43] and Seidu et al. [27] found no statistically significant difference on primary endpoints (Table *4*). In the population-level ITS study, Brady et al. [28] documented a significant difference between pre- and post-implementation slopes in T2DM-related bed-days per 1,000 patients (P = 0.04).

Summary of Findings and Certainty of Evidence

Table 5 summarizes the overall certainty of evidence for the two outcome domains according to GRADE judgments across all contributing studies. Given that no meta-analysis was conducted, effects are described narratively from published estimates (Table 4) rather than as pooled relative effects. Certainty of evidence for both domains remained very low as a result of risk of bias, inconsistency, and indirectness, with additional imprecision in the randomized acute body (Table 5).

Outcome domain	Studies (n)	Summary of effect	Certainty	GRADE domains downgraded
Direct acute diabetic emergencies and glycemic crises (DKA, HHS, severe hypoglycemia, or closely related acute measures)	7	Directionally lower acute or glycemic-crisis estimates were reported in all three family-medicine-core studies with acute endpoints (Chou et al. [36]; Tourkmani et al. [37]; Mohamed et al. [33]) and in one pharmacist-led trial (Gilliam et al. [35]); one multinational primary care RCT reported lower severe hypoglycemia (Ibrahim et al. [40]); one trial found no difference (Jia et al. [39]); and one claims cohort reported a small increase in coded hypoglycemia (Karimova et al. [29]). DKA and HHS appeared only within a composite endpoint (Chou et al. [36]).	Very low	Randomized track (four trials): starting certainty high; risk of bias −1 (three of four trials had some concerns); inconsistency −1 (Jia et al. [39] was null while the other three trials were favorable, and outcome definitions varied); imprecision −1 (the three favorable trials had sparse severe-hypoglycemia events and wide or unreported CIs: 0 vs. 5 events in Gilliam et al. [35], OR, 0.2 with 95% CI, 0.1-0.8 in Ibrahim et al.[40], and no CI in Mohamed et al. [33], whereas the largest trial, Jia et al. [39], was null); indirectness was not downgraded because all four trials directly enrolled adults with diabetes in primary or community care and measured hypoglycemia, whereas the symptom-score and composite endpoints belong to the non-randomized track. Final rating for this track: very low (high minus three levels). Non-randomized track (three studies): starting certainty low; risk of bias −1; inconsistency −1 (claims-defined hypoglycemia increased in Karimova et al. [29]); indirectness −1 (endpoints ranged from a composite acute outcome to a symptom score and claims-coded hypoglycemia); imprecision was not downgraded because the two large claims cohorts provided narrow CIs and the remaining symptom-score study reported a statistically significant between-group difference. Final rating for this track: very low (starting low; three concerns were recorded, and very low is the floor of the GRADE scale). Publication bias was not formally assessed for either track because fewer than 10 studies contributed to each and no pooling was performed. Both design-specific bodies were rated very low, so the single overall statement for the acute domain is very low; the two ratings are reported separately and were not averaged. No domain was upgraded.
Healthcare utilization (PAH, diabetes-related unplanned hospitalization, all-cause hospitalization, ED visits, or bed-days)	13	Eight studies reported at least one statistically significant favorable utilization estimate (Table 4): Zhang et al. [48], Wong et al. [47], Fortmann et al. [41], Georgescu et al. [42], Höglinger et al. [45], Lee and Kim [34], Carter et al. [38], and Brady et al. [28]. The Carter estimate was a qualified post-reform ED-visit trend, with a small absolute difference at year 9 and a significant early increase in the rural immediate level; the Brady estimate was a significant change in bed-day slope (P = 0.04) without a significant post-reform slope. Ha et al. [44] showed higher hospitalization rates among patients with lower GP coverage, indicating a protective association of greater GP continuity; Goff et al. [43] and Seidu et al. [27] were null on primary endpoints; and Moorin et al. [46] and Leutgeb et al. [30] reported favorable directions without clearly reported	Very low	Starting certainty: low (predominantly observational, including one ITS). Downgrades: risk of bias −1 (self-selection and confounding); indirectness −1 (heterogeneous measures ranging from PAH to all-cause admissions and emergency visits, with variable specificity to diabetes-related acute complications); inconsistency −1 (null primary endpoints in two practice-level studies and a qualified ED-visit trend in one ITS despite predominantly favorable direction in larger claims cohorts). Imprecision was not downgraded because the large claims cohorts provided precise estimates, although sparse events in some studies limited precision. Publication bias was not formally assessed because no pooled estimate was generated and the included studies were too heterogeneous in design and outcome definition for a meaningful funnel-plot assessment. Net certainty: very low. No domain was upgraded.

	significance.

TABLE 5: Summary of findings and GRADE certainty of evidence

Summary of effect: Effects are described narratively from published estimates; no pooled relative effects were calculated. Certainty: GRADE ratings of high, moderate, low, or very low.

DKA: diabetic ketoacidosis; HHS: hyperosmolar hyperglycemic state; ITS: interrupted time series; PAH: potentially avoidable hospitalization; ED: emergency department; GP: general practitioner; GRADE: Grading of Recommendations Assessment, Development and Evaluation; RCT: randomized controlled trial; OR: odds ratio; CI: confidence interval

Sensitivity Analyses

Six sensitivity analyses restricted interpretation to the four family-medicine-core studies, alternately excluded each member of the two overlapping cohort pairs, and separated Ramadan-focused interventions; Appendix F records the studies removed, the studies retained, the direction of findings before and after each restriction, and the effect on the interpretation. These analyses were exploratory, directional, and narrative: they tested the robustness of the narrative synthesis rather than producing new pooled estimates or recalculating study-level effect estimates. Excluding Karimova et al. [29] removed the conflicting claims-defined hypoglycemia finding from the acute analysis, whereas excluding Leutgeb et al. [30] or either Leicester study left the utilization direction unchanged; and non-Ramadan acute findings remained mixed, so Ramadan-specific results should not be generalized beyond fasting periods. No sensitivity analysis changed the direction of the overall interpretation or raised certainty above very low.

Discussion

Principal Findings

This review included 20 studies and found a directionally favorable but heterogeneous pattern: most family medicine and primary care interventions were associated with fewer acute glycemic events or lower utilization, but the certainty of evidence was very low for both domains, and several studies were null or conflicting. Four family-medicine-core studies provided the most direct evidence about family physician-led care or family medicine reform, although none supports causal inference. In particular, the Family Medicine Groups reform evaluated by Carter et al. [38] was followed by a statistically significant divergence from the pre-reform trend by year 9, but the immediate level change was non-significant in urban regions and represented an early increase in rural regions, the change-in-trend terms were not significant, and the absolute difference was small relative to baseline (about two visits per 10,000 patients per week). Administratively defined utilization outcomes should not be equated with adjudicated DKA, HHS, or severe hypoglycemia, and firm causal conclusions are not supported (Table *4*).

Interpretation in Relation to Previous Literature

Earlier observational studies [16-18,49,50], including a 23-country comparison of primary care organization and avoidable diabetes admissions, and systematic reviews [51,52] examined hospitalization, avoidable admission, or ED visits more often than DKA, HHS, or severe hypoglycemia as primary endpoints. These sources provide indirect background rather than direct evidence on acute emergencies. Financial incentives, integrated care models, and community follow-up after hypoglycemia demonstrated mixed effects by outcome type [52-56], helping situate-but not validate-the utilization findings in the present review.

In the retrospective cohort study by Chou et al. [36], the findings warrant careful interpretation because physician specialty assignment reflects patient self-selection and claims-based coding rather than random allocation; patients with a healthier or less complex state may prefer family physicians, whereas patients with an unhealthier state may seek endocrinologists, inducing confounding by indication that the adjusted hazard ratios may not fully remove. Additionally, the composite acute endpoint combined clinically distinct events (DKA, HHS, and hypoglycemia), thereby limiting inference to any single emergency type. Karimova et al. [29] reported a small increase in claims-coded hypoglycemia under GP-centered healthcare, likely reflecting intensified detection or coding differences instead of true clinical harm; thus, it should not be interpreted in isolation as program failure.

Much of the observed heterogeneity aligned with intervention type and endpoint definition rather than a uniform reorganization effect. Directionally favorable acute endpoints clustered around Ramadan-focused education, pharmacist-led safety review, and family physician-led pathways. Meanwhile, favorable utilization estimates were derived mainly from claims-based disease management or GP-centered contracts; null or conflicting findings under mHealth and some practice-enhancement models underscore that program scale and design matter. Continuity of contact, sick-day counseling, and proactive hypoglycemia review broadly align with continuity-centered family medicine [4,6,14,15]; the guidelines do not empirically

validate the review findings but rather state normative standards.

Strengths and Limitations

Although the eligibility criteria, PROSPERO registration, and explicit GRADE judgments constrained interpretive drift, most of the included studies were observational or quasi-experimental and carried important risks of bias. Only one trial was judged as low risk [35]. Most non-randomized interventional studies raised serious concerns based on ROBINS-I, and cohort analyses were vulnerable to self-selection.

Acute endpoints were inconsistently defined and rarely reported as discrete DKA or HHS events. Intervention content, comparators, and outcome definitions-alongside voluntary enrollment, possible rather than confirmed overlap of populations or data sources in Germany (claims-based cohorts) and Leicester (local enhanced-care cohorts), no DM-type stratification in source reports, and the inability to obtain full text for one potentially eligible report-demonstrated substantial heterogeneity, limiting comparability and precluding quantitative synthesis. The search was restricted to English-language studies published from 2015 onward, and one potentially eligible report could not be retrieved; these restrictions may have excluded relevant evidence. PROSPERO secondary outcomes (glycated hemoglobin and all-cause mortality) and a T1DM versus T2DM subgroup could not be analyzed because the included reports had no eligible endpoint data stratified in that way. Considering that most utilization studies were observational and several reported directionally favorable findings, selective publication cannot be ruled out; this uncertainty was weighed in the GRADE judgments for both outcome domains. Accordingly, the observed associations should be interpreted not as conclusive but as indicative and hypothesis-generating.

Implications for Family Medicine and Primary Care

Within these constraints, clinically transferable elements include care continuity, structured hypoglycemia-risk assessment, culturally adapted education, and pharmacist-supported medication safety in high-risk groups. For family medicine, these components are plausible parts of a preventive model, but the review does not establish that they prevent DKA or HHS. For policy and planning, utilization trends may provide insights into monitoring, but commissioners should audit coding validity, case-mix, and voluntary enrollment before treating hospitalization reductions as evidence of prevention of DKA, HHS, or severe hypoglycemia. Wholesale replication of incentive or contract models should remain setting-specific pending stronger comparative evidence.

Future Research

Future research should prioritize standardized, clinically validated definitions of the acute complications, longer follow-up, and consistent reporting by DM type, including registry-linked or cluster-randomized comparisons of family physician-led versus specialist-led care. Trials should report DKA and HHS as separate endpoints rather than only within composite measures, and should pre-specify absolute as well as relative effects so that clinical importance can be judged.

Conclusions

Overall, an organized primary care program combining continuity, structured education, pharmacist-supported safety initiatives, and coordinated follow-up may be associated with fewer acute glycemic events and lower related healthcare utilization. However, very low-GRADE certainty, substantial observational influence, and conflicting claims-based hypoglycemia findings require conditional rather than prescriptive recommendations. No included study reported DKA or HHS separately, so the review cannot confirm that family medicine prevents these specific emergencies. Uncritical expansion of contract or incentive models without acute-endpoint observation would be inadvisable.

Appendices

Appendix A

Database	Filters/limits	Search strategy
PubMed/MEDLINE	Humans; adult (≥18 years); 2015-2026; English; executed May 15, 2026	(("Diabetes Mellitus, Type 1"[MeSH Terms] OR "Diabetes Mellitus, Type 2"[MeSH Terms] OR "type 1 diabetes"[Title/Abstract] OR "type 2 diabetes"[Title/Abstract] OR T1DM[Title/Abstract] OR T2DM[Title/Abstract]) NOT ("Diabetes Insipidus"[MeSH Terms] OR "Diabetes, Gestational"[MeSH Terms])) AND ("Family Practice"[MeSH Terms] OR "Physicians, Family"[MeSH Terms] OR "General Practice"[MeSH Terms] OR "family medicine"[Title/Abstract] OR "family physician"[Title/Abstract] OR "general practice"[Title/Abstract] OR (("primary care"[Title/Abstract] OR "primary healthcare"[Title/Abstract]) AND ("diabetes mellitus"[Title/Abstract] OR "type 1 diabetes"[Title/Abstract] OR "type 2 diabetes"[Title/Abstract] OR T1DM[Title/Abstract] OR T2DM[Title/Abstract]))) AND ("Diabetic Ketoacidosis"[MeSH Terms] OR "Hyperglycemic Hyperosmolar Nonketotic Coma"[MeSH Terms] OR "diabetic ketoacidosis"[Title/Abstract] OR DKA[Title/Abstract] OR "hyperosmolar hyperglycemic state"[Title/Abstract] OR "hyperosmolar hyperglycaemic state"[Title/Abstract] OR HHS[Title/Abstract] OR "severe hypoglycemia"[Title/Abstract] OR "severe hypoglycaemia"[Title/Abstract] OR "preventable hospitalization"[Title/Abstract] OR "preventable hospitalisation"[Title/Abstract] OR "emergency department visit"[Title/Abstract]) AND ("2015/01/01"[Publication Date] : "2026/12/31"[Publication Date]) AND english[Language]
Scopus	Articles; English; 2015-2026; executed May 22, 2026	TITLE-ABS-KEY("type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM) AND TITLE-ABS-KEY("family medicine" OR "family physician" OR "general practice" OR (("primary care" OR "primary healthcare") AND ("diabetes mellitus" OR "type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM))) AND TITLE-ABS-KEY("diabetic ketoacidosis" OR DKA OR "hyperosmolar hyperglycemic state" OR "hyperosmolar hyperglycaemic state" OR HHS OR "severe hypoglycemia" OR "severe hypoglycaemia" OR "preventable hospitalization" OR "preventable hospitalisation" OR "emergency department visit") AND (PUBYEAR > 2014 AND PUBYEAR < 2027) AND LIMIT-TO(DOCTYPE, "ar") AND LIMIT-TO(LANGUAGE, "English") AND NOT TITLE-ABS-KEY("diabetes insipidus" OR "gestational diabetes")
Web of Science	Core Collection; 2015-2026; executed June 3, 2026	TS=("type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM) NOT TS=("diabetes insipidus" OR "gestational diabetes") AND TS=("family medicine" OR "family physician" OR "general practice" OR (("primary care" OR "primary healthcare") AND ("diabetes mellitus" OR "type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM))) AND TS=("diabetic ketoacidosis" OR DKA OR "hyperosmolar hyperglycemic state" OR "hyperosmolar hyperglycaemic state" OR HHS OR "severe hypoglycemia" OR "severe hypoglycaemia" OR "preventable hospitalization" OR "preventable hospitalisation" OR "emergency department visit") AND PY=(2015-2026)
Cochrane CENTRAL	Trials; 2015-2026; English; executed June 8, 2026. Three Title/Abstract/Keyword lines combined with AND	Line 1: ("type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM) NOT ("diabetes insipidus" OR "gestational diabetes") Line 2: ("family medicine" OR "family physician" OR "general practice") OR (("primary care" OR "primary healthcare") AND ("diabetes mellitus" OR "type 1 diabetes" OR "type 2 diabetes" OR T1DM OR T2DM)) Line 3: ("diabetic ketoacidosis" OR DKA OR "hyperosmolar hyperglycemic state" OR "hyperosmolar hyperglycaemic state" OR HHS OR "severe hypoglycemia" OR "severe hypoglycaemia" OR "preventable hospitalization" OR "preventable hospitalisation" OR "emergency department visit")

TABLE 6: Complete search strategies by database (May-June 2026)

The 2026 upper date limit in the PubMed filter is a filter boundary; the search was executed on May 15, 2026. Database-specific execution dates are also listed in Appendix B.

Appendix B

Source	Search date	Records identified (n)
PubMed/MEDLINE	May 15, 2026	1,547
Scopus	May 22, 2026	1,136
Web of Science (Core Collection)	June 3, 2026	3,236
Cochrane CENTRAL	June 8, 2026	28
Reference lists and supplementary PubMed update	June 2026	39
Total before deduplication	-	5,986
Duplicates removed	-	56
Unique records screened	-	5,930

TABLE 7: Database-specific identification counts and search dates

The 2026 upper date limit in the PubMed filter is a filter boundary; the search was executed on May 15, 2026.

Appendix C

Screening stage	Records assessed	Conflicts requiring discussion	Agreement before consensus
Title and abstract	5,930	71	98.8%
Full-text eligibility	26	1	96.2%

TABLE 8: Inter-rater agreement during study selection

Appendix D

#	Study	Country/region	Design	Population (n)	Intervention (primary/FM care)	Comparator	Outcome(s)	Follow-up	Key findings (published results)	Outcome focus
1	Chou et al. [36]	Taiwan	Retrospective cohort	206,819 newly diagnosed T2DM classified by primary physician in year 1; pairwise matched cohorts: FM vs. IM (n = 28,269 each), FM vs. endocrinology (n = 23,407 each), IM vs. endocrinology (n = 43,693 each)	Care by family physicians (patients with >50% of diabetes visits to FM in the first year after diagnosis): process monitoring including HbA1c, lipid profile, and urinary ACR during follow-up	Endocrinologist-led care; other internist-led care (cardiology, nephrology, general medicine, neurology)	DKA; HHS; hypoglycemia	24 months (2-year follow-up after index diagnosis)	FM vs. endocrinology (matched): acute complications 1.29% vs. 2.05% (P < 0.001). FM vs. IM (matched): 1.42% vs. 2.35% (P < 0.001). Compared with FM as reference, endocrinology sHR 1.57 (95% CI, 1.38-1.78) and IM sHR 1.26 (95% CI, 1.08-1.47) for DKA, HHS, or hypoglycemia (Fine-Gray subdistribution hazard model).	Direct acute
2	Tourkmani et al. [37]	Saudi Arabia	Non-randomized controlled	262 adults with T2DM (140 intervention/122 control)	RFEP at Al-Wazarat Family Medicine Center (Riyadh): clinical pharmacist + family physician + dietitian education; medication adjustment; acute complication counseling	Standard diabetic care in same primary care center	Hypoglycemia score; HbA1c; acute complications (baseline)	~6 months (pre/during/post-Ramadan; HbA1c at 12 weeks post-Ramadan)	Primary outcomes: hypoglycemia score and HbA1c. Hypoglycemia scores (before/during/after Ramadan): 14.21/6.36/5.44 (intervention) vs. 14.01/13.46/9.27 (control); between-group difference at end P < 0.001. Post-Ramadan hypoglycemia score reduction −61.7% vs. −33.8% (P < 0.001); HbA1c reduction −13.0% vs. −4.5% (P = 0.004). Target HbA1c (<7) after Ramadan: 19.3% vs. 3.3% (P < 0.001). Acute complications at baseline: 0% vs. 4.9% (P = 0.008).	Direct acute

3	Mohamed et al. [33]	United Arab Emirates	RCT	60 adults with T2DM (30 per arm); single-blind RCT at Al Bateen Primary Healthcare Clinic, Abu Dhabi (AHS)	PRINTED 1: pre-Ramadan structured education by trained family physician at Al Bateen Primary Healthcare Clinic (medication review, risk stratification, SMBG guidance per DAR/IDF)	Standard/usual diabetic care	Hypoglycemia frequency	~1 month Ramadan fasting period (mean 27 ± 7.1 vs. 28 ± 6.3 days fasted) + pre-Ramadan baseline and during-Ramadan outcome assessment	Baseline hypoglycemia frequency similar: 40% (intervention) vs. 33.3% (control; P > 0.05). During Ramadan: intervention 40% → 16.7% (50% reduction; P = 0.003); control unchanged 33.3%. Medication review/modification: 100% intervention vs. 36.6% control (P < 0.05).	Direct acute
4	Gilliam et al. [35]	United States	RCT	191 adults with T2DM at high hypoglycemia risk (ITT; 200 enrolled from 1,204 eligible) at Kaiser Permanente Northern California; mean age 71.3 years; 85%-90% on insulin	Proactive, protocol-driven clinical pharmacist outreach embedded in collaborative primary care teams using Hypoglycemia on a Page (HOAP): medication deprescribing (sulfonylureas/short-acting insulin), individualized glycemic targets, hypoglycemia education, referrals (~3 pharmacist contacts)	Usual primary care team management (no proactive pharmacist outreach)	Severe hypoglycemia (ED/inpatient); safer prescribing	6 months (trial Jul 2023-Jan 2024; outcomes through Jan 2025)	Hypoglycemia-related ED or inpatient encounters: 0 vs. 5 (5.3%) intervention vs. control (RD −5.3%, 95% CI, −11.8% to −1.3%). Safer diabetes regimens (discontinued sulfonylurea and/or short-acting/mixed insulin): 28.1% vs. 15.8% (RD +12.3%, 95% CI, 0.6% to 24.0%). HbA1c < 8% preserved: 61.8% vs. 63.6% (RD −1.8%, 95% CI, −17.0% to 13.5%).	Direct acute
5	Karimova et al. [29]	Germany	Retrospective cohort	217,964 adults with T1/T2 diabetes (AOK Baden-Württemberg claims 2011-2020): 119,355 in GPCHC (HZV) vs. 98,609 in usual GP care	GPCHC (HZV): voluntary enrolment with coordinating GP, gatekeeping, structured chronic-care coordination, and high DMP participation	Usual GP care without HZV enrolment	Hypoglycemia (claims-defined); diabetes complications (blindness, amputation, MI, stroke, CHD, dialysis, mortality)	10 years (2011-2020)	Adjusted Cox models (relative risk reduction = (1 − HR) × 100): HZV vs. usual care - blindness −12%, amputation −20.3%, MI −14.9%, dialysis −10.1%, all-cause mortality −2.9%; stroke and CHD also significantly lower. Hypoglycemia was the only endpoint not favoring HZV (+1.2% higher hazard; authors attribute to more intensive treatment/monitoring). Administrative endpoints from claims, not ED visit counts.	Direct acute
6	Zhang et al. [48]	Australia	Prospective controlled trial	327 adults with complex T2DM	Multidisciplinary, community-based, integrated primary-secondary care diabetes service (Inala model: GP-led community care with specialist interface)	Usual care at hospital diabetes outpatient clinic (tertiary specialist-led)	Potentially preventable hospitalizations (diabetes-related principal diagnosis)	24 months after trial commencement (linked data also included 12 months pre-trial)	In the 24 months after study commencement, IRR for potentially preventable hospitalization with a diabetes-related principal diagnosis = 0.53 (95% CI, 0.29-0.96; P = 0.04); adjusted for age, sex, education, and baseline HbA1c: IRR, 0.54 (95% CI, 0.29-1.01; P = 0.05).	Utilization
7	Wong et al. [47]	Hong Kong	Matched cohort	24,250 T2DM patients evaluated in primary care; 12,125 with ≥1 PEP session vs. 12,125 propensity-score-matched non-participants	PEP: structured diabetes education in primary care with collaborative self-management	No PEP participation (usual primary care)	All-cause hospitalization; ED visits	Median 30.5 months	Initial hospitalization: 22.1% (PEP) vs. 25.2% (non-PEP); HR 0.879 (P < 0.001). Initial ED visit: 40.5% vs. 44.0%; HR 0.901 (P < 0.001). Number of hospitalizations: 16.9 vs. 20.0 per 100 patients/year; IRR, 0.854 (P < 0.001). Number of ED visits: 36.2 vs. 40.4 per 100 patients/year; IRR, 0.903 (P < 0.001).	Utilization
8	Goff et al. [43]	United States	Controlled before-after	319 patients with T2D: 72 Buena Salud enrollees + 247 controls (Brightwood Health Center, western Massachusetts Medicaid; largely Hispanic)	Buena Salud team-based enhanced primary care: 2 RN care managers, 2 community health workers (MAs), caseworker supporting PCP panel	Usual primary care controls at same health center (3:1 matched by clinic visit timing, not individual covariates)	Unplanned hospitalizations; ED visits	12-15 months post-enrolment/index	Unplanned hospitalizations: annual rate −2.8% (Buena Salud) vs. +8.9% (controls); DID −11.7% (P = 0.06 unadjusted; P = 0.11 adjusted)-trend only. No significant difference in ED visit rates between groups. Significant process outcome: microalbumin/creatinine measurement DID +22.2% (P = 0.008). No improvement in A1C, BP (except DBP rise in intervention), or LDL.	Utilization

9	Fortmann et al. [41]	United States	Pragmatic quasi-experimental (2-clinic case-control)	475 adults with T1/T2DM at 2 Scripps primary care clinics, Southern California (236 CMC-TI/239 usual care; ~97% T2DM)	Cardiometabolic care team in primary care: RN/CDE care manager, MA health coach, depression care manager with structured protocols	Usual primary care diabetes management (separate clinic)	Inpatient utilization; ED visits; total healthcare costs	12-month intervention; pre/post 1-year utilization periods compared	Time-by-group interactions significant for all inpatient utilization outcomes (P < 0.05). Post-period: mean ED visits 0.04 vs. 0.17 (P = 0.002); hospitalizations 0.05 vs. 0.19 (P = 0.004); ≥1 inpatient encounter 5% vs. 16% (P < 0.001). Total healthcare costs decreased 12.6% in CMC-TI vs. increased 51.7% in usual care (including program costs).	Utilization
10	Moorin et al. [46]	Australia (NSW)	Retrospective cross-sectional linkage (45 and Up Study + APDC/EDDC/MBS)	27,409 adults with diabetes with ≥2 GP visits in prior year (45 and Up Study, NSW)	Higher continuity-adjusted regularity of GP contact (evenly dispersed visits across quintiles)	Lower regularity quintiles (cross-sectional comparison)	Unplanned diabetes-related hospitalization or ED presentation; bed-days; costs	Cross-sectional linkage (diabetes-related unplanned events in study period)	Highest vs. lowest regularity quintile: 19.9% vs. 23.5% with any unplanned diabetes-related event. Conditional on event: −6% to −8% repeat events, −30% to −44% bed-days, −23% to −41% cost. Provider continuity did not modify regularity effect.	Utilization
11	Georgescu et al. [42]	France	Population cohort (French EGB national health insurance sample, 2011-2013)	25,293 adults with diabetes (1/97 SNDS representative sample)	Frequency of GP encounters during exposure period (2011-2012)	Fewer GP visits (dose-response reference categories)	First PAH in 2013-includes short-term complications of diabetes	Exposure 2011-2012; PAH outcome in 2013	10-14 GP visits vs. fewer: PAH aHR 0.49 (P < 0.001); 15-21 visits aHR 0.62 (P = 0.076). Protective effect of GP contact against PAH; majority of PAH events were non-diabetes (CHF/COPD).	Utilization
12	Höglinger et al. [45]	Switzerland	Prospective observational (DID)	538 DMP enrollees vs. 5,050 usual-care controls (SWICA claims; Medbase primary care); medicated T1/T2DM identified by pharmaceutical cost groups (diet-treated T2DM excluded)	Structured diabetes DMP in Swiss primary care: coordinated GP-led monitoring, education, and follow-up	Usual primary care without DMP	Hospitalization risk; guideline-adherent care	24 months (1- and 2-year follow-up)	Guideline-adherent care (all 4 measures): DID +7.2 pp at 1 year (P < 0.01) and +8.4 pp at 2 years (P < 0.001). Hospitalization risk DID −5.7 pp at 1 year (95% CI, −11.0 to −0.7; P < 0.05); −3.9 pp at 2 years (95% CI, −8.5 to 0.7; n.s.). Healthcare cost increase smaller in DMP (DID CHF −852/−909) but not statistically significant.	Utilization
13	Lee and Kim [34]	South Korea	Retrospective cohort	1,817,682 adults with T2DM in national claims (2019 index): 49,449 primary care CDMP participants vs. 1,768,233 non-participants (prior diabetes hospitalization excluded)	Korean primary care CDMP: designated clinic-based structured chronic disease management with copayment incentives, physician education/counseling, and coordinated follow-up in community primary care	Usual primary care without CDMP enrolment	Preventable diabetes-related hospitalization; IHD/stroke	Up to 4 years (index 2019 to Dec 2023)	CDMP vs. non-CDMP: any adverse outcome HR 0.867 (95% CI, 0.848-0.887); preventable diabetes-related hospitalization HR 0.729 (95% CI, 0.696-0.764); stroke HR 0.851; IHD HR 0.940.	Utilization
14	Leutgeb et al. [30]	Germany	Retrospective cohort (cross-section + longitudinal)	~1.93 million insured adults (AOK Baden-Württemberg, 2022 cross-section; 3.83 million patient-years 2011-2022): GPCHC/HZV enrollees vs. regular primary care	GPCHC: coordinating GP, structured chronic-care pathways including diabetes DMP, reduced uncoordinated specialist visits	Regular primary care without GPCHC contract	PAH; all-cause hospitalization	12-year longitudinal (2011-2022); primary comparison year 2022	2022 cross-section: GPCHC vs. regular care-all-cause hospitalizations −8.61%; PAH −2.46% (per 100 individuals). Longitudinal analyses (2011-2022) showed sustained lower PAH and all-cause hospitalization rates in GPCHC enrollees; fewer uncoordinated non-GP specialist consultations.	Utilization
				19,546 adults with T2DM registered in community	ROADMAP: mHealth-enabled three-tiered hierarchical diabetes	Usual essential public health	Hypoglycemia		Intervention improved HbA1c and composite	

15	Jia et al. [39]	China	Cluster RCT	primary care (864 clusters; 13,037 intervention/6,509 usual care after randomization)	management in primary care (monthly structured monitoring, tiered care team, graded ROADMAP platform)	service primary care (annual monitoring and instruction)	episodes; HbA1c control	12 months	ABC control vs. usual care (ITT GEE). No significant difference in hypoglycemia episodes between groups.	Direct acute
16	Ha et al. [44]	Australia (NSW)	Retrospective cohort (45 and Up Study; 3-year baseline + 3-year follow-up)	21,965 adults ≥ 45 years with diabetes (45 and Up Study, NSW)	Longitudinal GP cover index-proportion of time under potentially protective GP contact (perfect vs. high/medium/low cover)	Perfect GP cover (reference)	Diabetes-related hospitalization; unplanned diabetes-related hospitalization; length of stay	3-year follow-up after 3-year baseline period	vs. perfect cover (doubly robust): diabetes-related hospitalization IRR, 2.8 (high), 3.2 (medium), 3.1 (low). Unplanned diabetes-related hospitalization IRR, 1.7 (medium and high cover vs. perfect). Lower GP cover associated with more unplanned diabetes hospitalizations.	Utilization
17	Carter et al. [38]	Canada (Quebec)	Population ITS (segmented regression)	Open cohort of adults (≥20 y) with T1/T2 diabetes in Quebec administrative data: 275,728 (2000) → 533,438 (2011); weekly ED rates 626 weeks (Apr 2000-Mar 2012)	Family Medicine Groups (FMG): province-wide primary care reform (Nov 2002+)-team-based FM practices, enrolment, extended hours, nurse-supported access, inter-professional delivery	Counterfactual pre-reform trend extrapolation (ITS); negative outcome control: ED visits for appendicitis (expected unaffected by FMG)	ED-acute diabetes-related complications; hypo-/hyperglycemic emergencies (CIHI ACSC ICD-9)	12 years (9 years post-FMG reform to 2011)	Post-reform slope in avoidable ED visits: RR 0.99 (95% CI, 0.98-0.99) per week, corresponding to about a 1% reduction per week, in urban and rural areas. At 9 years post-reform, the absolute difference from the predicted rate was −2.12 (95% CI, −2.94 to −1.29) visits per 10,000 patients/week in urban areas and −2.25 (95% CI, −3.64 to −0.85) in rural areas. The immediate level change was not statistically significant in urban areas (RR 1.04; 95% CI, 0.98-1.10) but showed a significant early increase in rural areas (RR 1.12; 95% CI, 1.04-1.20); change-in-trend terms were not significant in either region (RR 0.99; 95% CI, 0.99-1.00). Appendicitis ED control series unchanged (RR 1.00; 95% CI, 0.99-1.01).	Utilization
18	Seidu et al. [27]	United Kingdom (Leicester)	Before-after (practice-level)	8 enhanced primary care practices vs. 8 matched neighboring control ("core") practices	Enhanced primary care model: GPs and nurses with an interest in diabetes attending monthly education meetings and providing care plans and audits	Core practices providing integrated primary-specialist (specialist-community) diabetes service	Non-elective bed-days; diabetes complication admissions	12 months	Difference in mean change from baseline to follow-up between enhanced and core practices: non-elective bed-days +2.20 per 100 patients (95% CI, −0.92 to 5.31; P = 0.14). Diabetes-related complication admissions +0.30 per 100 patients (95% CI, −0.85 to 1.45; P = 0.55)-no statistically significant excess vs. core integrated service.	Utilization
19	Brady et al. [28]	United Kingdom	Quasi-experimental ITS	Population-level T2DM cohort across Leicester, Leicestershire, and Rutland; Leicester City CCG (sole site implementing full Transformation model) = primary evaluation population	Transformation model: shift of diabetes services from secondary to primary/community care with locality-based community diabetes specialists supporting GPs	Pre- vs. post-implementation trend within primary population (ITS); secondary analyses: other Leicestershire CCGs and national trends for secular change	T2DM-related bed-days per 1,000 patients	Multiyear (pre/post-implementation)	Mean T2DM-related bed-days per 1,000 patients increasing pre-implementation (+0.33/month; 95% CI, −0.07 to 0.72) vs. decreasing post-implementation (−0.14/month; 95% CI, −0.33 to 0.06); difference between slopes P = 0.04.	Utilization
20	Ibrahim et al. [40]	Multinational (5 Muslim-majority countries)	Multinational RCT (open-label)	452 adults with T2DM analyzed (231 intervention/221 control; 506 enrolled; Ramadan 2021 cycle)	Pre-Ramadan assessment + structured education + glucose-lowering treatment adjustment per ADA/EASD 2020 Ramadan consensus recommendations (delivered in primary care; family physician leadership not separately reported)	Local usual care (control)	Hypoglycemic episodes; severe hypoglycemia; HbA1c; weight; lipids	Ramadan fasting period + pre/post assessment (~12.6%/8.7% loss to follow-up)	Intervention group: fewer hypoglycemic episodes overall vs. usual care. Severe hypoglycemia OR, 0.2 (95% CI, 0.1-0.8) vs. control. Greater HbA1c reduction in intervention group.	Direct acute

TABLE 9: Extended characteristics and published findings for included studies (n = 20)

FM: family medicine; IM: internal medicine; RCT: randomized controlled trial; ITS: interrupted time series; ITT: intention-to-treat; DKA: diabetic ketoacidosis; HHS: hyperosmolar hyperglycemic state; ED: emergency department; GP: general practitioner; PAH: potentially avoidable hospitalization; HR: hazard ratio; sHR: subdistribution hazard ratio; aHR: adjusted hazard ratio; IRR: incidence rate ratio; OR: odds ratio; RD: risk difference; DID: difference-in-differences; DMP: disease management program; CDMP: Chronic Disease Management Program; HZV: Hausarztzentrierte Versorgung; GPCHC: GP-centered healthcare; T2DM: type 2 diabetes mellitus; ACR: albumin-creatinine ratio; CI: confidence interval; RFEP: Ramadan focused education program; SMBG: self-monitoring of blood glucose; DAR: Diabetes and Ramadan; IDF: International Diabetes Federation; MI: myocardial infarction; CHD: coronary heart disease; PEP: Patient Empowerment Program; BP: blood pressure; DBP: diastolic blood pressure; LDL: low-density lipoprotein; CMC-TI: cardiometabolic care team intervention; CDE: certified diabetes educator; MA: medical assistant; NSW: New South Wales; APDC: Admitted Patient Data Collection; EDDC: Emergency Department Data Collection; MBS: Medical Benefits Schedule; EGB: Echantillon Généraliste de Bénéficiaires; SNDS: Système National des Données de Santé; GEE: generalized estimating equation; CIHI: Canadian Institute for Health Information; ACSC: ambulatory care sensitive conditions; CCG: Clinical Commissioning Group; ADA: American Diabetes Association; EASD: European Association for the Study of Diabetes; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; IHD: ischemic heart disease

Appendix E

Study	Category	Evidence basis for classification
Family-medicine core (n = 4)		
Chou et al. [36]	A. Family physician-led care	Diabetes care led by family physicians compared with endocrinologist- or internist-led care.
Mohamed et al. [33]	A. Family physician-led care	Pre-Ramadan education delivered by a trained family physician in a primary healthcare clinic.
Tourkmani et al. [37]	B. Structured family medicine-based program	Ramadan-focused program delivered at a family medicine center by a family physician, clinical pharmacist, and dietician.
Carter et al. [38]	B. Structured family medicine-based program	Province-wide Family Medicine Groups reform of team-based family medicine practices.
Structured primary care, not specific to family medicine (n = 13)		
Ibrahim et al. [40]	C. Structured primary care program	Multinational pre-Ramadan education and treatment adjustment in primary care; family physician leadership not separately reported.
Gilliam et al. [35]	C. Structured primary care program	Pharmacist-led outreach within collaborative primary care teams; not family physician-led.
Jia et al. [39]	C. Structured primary care program	mHealth-enabled hierarchical diabetes management in community primary care.
Zhang et al. [48]	C. Structured primary care program	Integrated primary-secondary care service with GP-led community care and specialist interface.
Fortmann et al. [41]	C. Structured primary care program	Cardiometabolic care team embedded in primary care.
Wong et al. [47]	C. Structured primary care program	Structured diabetes education program in primary care.
Goff et al. [43]	C. Structured primary care program	Enhanced primary care program with care managers and community health workers.
Höglinger et al. [45]	C. Structured primary care program	Primary care disease-management program.
Lee and Kim [34]	C. Structured primary care program	National primary care chronic disease management program.
Leutgeb et al. [30]	C. Structured primary care program	GP-centered healthcare contract with structured chronic-care pathways.
Seidu et al. [27]	C. Structured primary care program	Enhanced primary care diabetes service with GP and nurse education.
Brady et al. [28]	C. Structured primary care program	Transformation model shifting diabetes services from secondary to primary/community care.
Karimova et	C. Structured primary care	

al. [29]	program	GP-centered healthcare contract with structured chronic-care coordination.
Primary care exposure or continuity only (n = 3)		
Moorin et al. [46]	D. General primary care exposure	Continuity-adjusted regularity of GP contact, without a structured intervention.
Georgescu et al. [42]	D. General primary care exposure	Frequency of GP visits, without a structured intervention.
Ha et al. [44]	D. General primary care exposure	Longitudinal GP cover index, without a structured intervention.

TABLE 10: Classification of included studies by family medicine involvement (n = 20)

Categories: A, family physician-led care; B, structured family medicine-based program or reform; C, structured primary care program not specific to family medicine; D, general primary care exposure or continuity. Category E (specialist-led or other comparator models) was not used because no included study evaluated a specialist-led intervention as the primary intervention. Classification was based on the published description of the intervention and setting, not on the direction of findings. Ibrahim et al. [40] is the least certain assignment because family physician leadership was not separately reported; it was therefore not counted among the four family-medicine-core studies in the main analysis.

Appendix F

Analysis	Studies removed	Retained (n)	Acute direction	Utilization direction	Effect on interpretation
Primary narrative synthesis	None	20	Predominantly favorable but mixed (7 studies)	Predominantly favorable but mixed (13 studies)	Reference interpretation; certainty very low in both domains
Family-medicine-core studies only	All 16 non-core studies	4	Favorable (Chou et al., Mohamed et al., Tourkmani et al.)	Favorable, qualified (Carter et al.)	Direction unchanged; certainty remains very low
Excluding Seidu et al. [27]	Seidu et al. [27]	19	Unchanged	Brady et al. [28] remains favorable; direction unchanged	Interpretation unchanged
Excluding Brady et al. [28]	Brady et al. [28]	19	Unchanged	Seidu et al. [27] remains null; direction unchanged	Interpretation unchanged
Excluding Karimova et al. [29]	Karimova et al. [29]	19	Claims-defined hypoglycemia increase removed; direction remains mixed (Jia et al. vs. favorable trials)	Leutgeb et al. [30] remains favorable	Interpretation unchanged; inconsistency slightly reduced
Excluding Leutgeb et al. [30]	Leutgeb et al. [30]	19	Unchanged (Karimova et al. unfavorable; Jia et al.; other trials favorable)	Direction unchanged	Interpretation unchanged
Excluding Ramadan-focused studies	Mohamed et al. [33]; Tourkmani et al. [37]; Ibrahim et al. [40]	17	Mixed (Chou et al. and Gilliam et al. favorable; Jia et al.; Karimova et al. unfavorable)	Unchanged	Ramadan-specific contribution removed; overall direction unchanged; certainty very low

TABLE 11: Primary narrative synthesis and six sensitivity analyses (n = 20)

Directions are those reported by the included studies and tabulated in Table 4; no pooled estimate was recalculated. Unchanged indicates the same narrative direction and the same very-low certainty rating. Alternating exclusion of overlapping pairs follows the approach described in the Methods section.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Majed Algaed, Omar Alanazi, Layan Alzahrani, Kadi Alfurayh, Hind Alabdullatif, Saqib Ali, Fahad Alruwaili

Acquisition, analysis, or interpretation of data: Majed Algaed, Omar Alanazi, Layan Alzahrani, Kadi Alfurayh, Hind Alabdullatif, Saqib Ali, Najeeb Alshamy, Fahad Alruwaili

Drafting of the manuscript: Majed Algaed, Omar Alanazi, Layan Alzahrani, Kadi Alfurayh, Hind Alabdullatif, Saqib Ali, Fahad Alruwaili

Critical review of the manuscript for important intellectual content: Majed Algaed, Omar Alanazi, Layan Alzahrani, Kadi Alfurayh, Hind Alabdullatif, Saqib Ali, Najeeb Alshamy, Fahad Alruwaili

Supervision: Majed Algaed, Omar Alanazi, Layan Alzahrani, Kadi Alfurayh, Hind Alabdullatif, Saqib Ali

Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Genitsaridi I, Salpea P, Salim A, et al.: 11th edition of the IDF Diabetes Atlas: global, regional, and national diabetes prevalence estimates for 2024 and projections for 2050. Lancet Diabetes Endocrinol. 2026, 14:149-56. 10.1016/S2213-8587(25)00299-2
2. World Health Organization. Diabetes. (2024). Accessed: June 7, 2026: https://www.who.int/news-room/fact-sheets/detail/diabetes.
3. International Diabetes Federation: IDF Diabetes Atlas, 11th edition. International Diabetes Federation, Brussels; 2025. https://diabetesatlas.org/resources/idf-diabetes-atlas-2025/.
4. Dhatariya KK, Glaser NS, Codner E, Umpierrez GE: Diabetic ketoacidosis. Nat Rev Dis Primers. 2020, 6:40. 10.1038/s41572-020-0165-1
5. Shaka H, El-Amir Z, Wani F, et al.: Hospitalizations and inpatient mortality for hyperosmolar hyperglycemic state over a decade. Diabetes Res Clin Pract. 2022, 185:109230. 10.1016/j.diabres.2022.109230
6. American Diabetes Association Professional Practice Committee: 6. Glycemic Goals and Hypoglycemia: Standards of Care in Diabetes-2024. Diabetes Care. 2024, 47:S111-25. 10.2337/dc24-S006
7. O'Reilly JE, Jeyam A, Caparrotta TM, et al.: Rising rates and widening socioeconomic disparities in diabetic ketoacidosis in type 1 diabetes in Scotland: a nationwide retrospective cohort observational study. Diabetes Care. 2021, 44:2010-7. 10.2337/dc21-0689
8. Misra S, Barron E, Vamos EP, et al.: Temporal trends in emergency admissions for diabetic ketoacidosis in people with diabetes in England before and during the COVID-19 pandemic: a population-based study. Lancet Diabetes Endocrinol. 2021, 9:671-80. 10.1016/S2213-8587(21)00208-4
9. Benoit SR, Hora I, Pasquel FJ, Gregg EW, Albright AL, Imperatore G: Trends in emergency department visits and inpatient admissions for hyperglycemic crises in adults with diabetes in the U.S., 2006-2015. Diabetes Care. 2020, 43:1057-64. 10.2337/dc19-2449
10. Zaccardi F, Davies MJ, Dhalwani NN, et al.: Trends in hospital admissions for hypoglycaemia in England: a retrospective, observational study. Lancet Diabetes Endocrinol. 2016, 4:677-85. 10.1016/S2213-8587(16)30091-2
11. Berthon W, McGurnaghan SJ, Blackbourn LAK, et al.: Ongoing burden and recent trends in severe hospitalised hypoglycaemia events in people with type 1 and type 2 diabetes in Scotland: a nationwide cohort study 2016-2022. Diabetes Res Clin Pract. 2024, 210:111642. 10.1016/j.diabres.2024.111642
12. Brandstaetter E, Bartal C, Sagy I, Jotkowitz A, Barski L: Recurrent diabetic ketoacidosis. Arch Endocrinol Metab. 2019, 63:531-5. 10.20945/2359-3997000000158
13. James S, Annetts K, Frakking T, et al.: Diabetic ketoacidosis presentations in a low socio-economic area: are services suitable?. BMC Health Serv Res. 2021, 21:682. 10.1186/s12913-021-06715-7
14. WONCA Europe: The European Definition of General Practice/Family Medicine. WONCA Europe, Brussels; 2023. https://www.woncaeurope.org/file/41f61fb9-47d5-4721-884e-603f4afa6588/WONCA_European_Definitions_2_v7.pdf.
15. National Institute for Health and Care Excellence. Type 2 diabetes in adults: management (NICE guideline NG28). (2015). Accessed: June 7, 2026: https://www.nice.org.uk/guidance/ng28.
16. Li YC: Continuity of care for newly diagnosed diabetic patients: a population-based study . PLoS One. 2019, 14:e0221327. 10.1371/journal.pone.0221327
17. Davis J, Lim E, Taira DA, Chen J: Relation of the networks formed by diabetic patients sharing physicians

with emergency department visits and hospitalizations. Med Care. 2020, 58:800-4. 10.1097/MLR.0000000000001378
18. Gunn LH, McKay AJ, Molokhia M, Valabhji J, Molina G, Majeed A, Vamos EP: Associations between attainment of incentivised primary care indicators and emergency hospital admissions among type 2 diabetes patients: a population-based historical cohort study. J R Soc Med. 2021, 114:299-312. 10.1177/01410768211005109
19. Page MJ, McKenzie JE, Bossuyt PM, et al.: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021, 372:n71. 10.1136/bmj.n71
20. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A: Rayyan—a web and mobile app for systematic reviews. Syst Rev. 2016, 5:210. 10.1186/s13643-016-0384-4
21. Sterne JA, Savović J, Page MJ, et al.: RoB 2: a revised tool for assessing risk of bias in randomised trials . BMJ. 2019, 366:l4898. 10.1136/bmj.l4898
22. Sterne JAC, Hernán MA, Reeves BC, et al.: ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016, 355:i4919. 10.1136/bmj.i4919
23. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. (2012). Accessed: June 7, 2026: https://ohri.ca/en/who-we-are/core-facilities-and-platforms/ottawa-methods-centre/newcastle-ottawa-scale.
24. Cochrane Effective Practice and Organisation of Care. Suggested risk of bias criteria for EPOC reviews . (2017). Accessed: June 7, 2026: https://epoc.cochrane.org/sites/epoc.cochrane.org/files/public/uploads/Resources-for-authors2017/suggested_risk_of_bi....
25. Popay J, Roberts H, Sowden A, et al.: Guidance on the Conduct of Narrative Synthesis in Systematic Reviews: A Product From the ESRC Methods Programme. Lancaster University, Lancaster; 2006. 10.13140/2.1.1018.4643
26. Campbell M, McKenzie JE, Sowden A, et al.: Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ. 2020, 368:l6890. 10.1136/bmj.l6890
27. Seidu S, Bodicoat DH, Davies MJ, et al.: Evaluating the impact of an enhanced primary care diabetes service on diabetes outcomes: a before-after study. Prim Care Diabetes. 2017, 11:171-7. 10.1016/j.pcd.2016.09.005
28. Brady EM, Bodicoat DH, Zaccardi F, et al.: Effectiveness of the Transformation model, a model of care that integrates diabetes services across primary, secondary and community care: a retrospective study. Diabet Med. 2021, 38:e14504. 10.1111/dme.14504
29. Karimova K, Friedmacher CM, Lemke D, Glushan A: Development of diabetes complications within coordinated and structured primary health care: a 10-year retrospective cohort study in Germany. BJGP Open. 2024, 8:BJGPO.2024.0061. 10.3399/BJGPO.2024.0061
30. Leutgeb R, Fuchs GE, Altiner A, Laux G: General-practitioner-centered health care: current results from the implementation of the German model. Sci Rep. 2026, 16:8562. 10.1038/s41598-026-43163-x
31. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schünemann HJ: GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008, 336:924-6. 10.1136/bmj.39489.470347.AD
32. Schünemann H, Brożek J, Guyatt G, Oxman A: GRADE Handbook. The GRADE Working Group, 2013.
33. Mohamed OMI, Hassanein M, Syeed A, et al.: Impact of pre-Ramadan intervention program on diabetic patients (PRINTED 1): a randomised controlled trial in a family medicine clinic-Abu Dhabi. World Fam Med J. 2019, 17:10-22. 10.5742/MEWFM.2019.93594
34. Lee SH, Kim KH: Long-term effectiveness of a primary care chronic disease management program in Korea . Epidemiol Health. 2026, 48:e2026023. 10.4178/epih.e2026023
35. Gilliam LK, Parker MM, Chen MW, Karter AJ, Grant RW: Pharmacist intervention for safer prescribing in patients with type 2 diabetes at high risk: a randomized clinical trial. JAMA Netw Open. 2026, 9:e2559946. 10.1001/jamanetworkopen.2025.59946
36. Chou PL, Chiang IH, Lin CW, et al.: Newly diagnosed type 2 diabetes care between family physicians, endocrinologists, and other internists in Taiwan: a retrospective population-based cohort study. J Pers Med. 2022, 12:461. 10.3390/jpm12030461
37. Tourkmani AM, Hassali MA, Alharbi TJ, et al.: Impact of Ramadan focused education program on hypoglycemic risk and metabolic control for patients with type 2 diabetes. Patient Prefer Adherence. 2016, 10:1709-17. 10.2147/PPA.S113324
38. Carter R, Quesnel-Vallée A, Plante C, Gamache P, Lévesque JF: Effect of family medicine groups on visits to the emergency department among diabetic patients in Quebec between 2000 and 2011: a population-based segmented regression analysis. BMC Fam Pract. 2016, 17:23. 10.1186/s12875-016-0422-2
39. Jia W, Zhang P, Zhu D, Duolikun N, Li H, Bao Y, Li X: Evaluation of an mHealth-enabled hierarchical diabetes management intervention in primary care in China (ROADMAP): a cluster randomized trial. PLoS Med. 2021, 18:e1003754. 10.1371/journal.pmed.1003754
40. Ibrahim M, Barker MM, Ahmad E, et al.: Optimizing Ramadan fasting: a randomised controlled trial for people with type 2 diabetes during Ramadan applying the principles of the ADA/EASD consensus. Diabetes Metab Res Rev. 2023, 39:e3604. 10.1002/dmrr.3604
41. Fortmann AL, Walker C, Barger K, et al.: Care team integration in primary care improves one-year clinical and financial outcomes in diabetes: a case for value-based care. Popul Health Manag. 2020, 23:467-75. 10.1089/pop.2019.0103
42. Georgescu V, Green A, Jensen PB, Möller S, Renard E, Mercier G: Primary care visits can reduce the risk of potentially avoidable hospitalizations among persons with diabetes in France. Eur J Public Health. 2020, 30:1056-61. 10.1093/eurpub/ckaa137
43. Goff SL, Murphy L, Knee AB, Guhn-Knight H, Guhn A, Lindenauer PK: Effects of an enhanced primary care program on diabetes outcomes. Am J Manag Care. 2017, 23:e75-81.
44. Ha NT, Harris M, Preen D, Moorin R: Time protective effect of contact with a general practitioner and its association with diabetes-related hospitalisations: a cohort study using the 45 and Up Study data in

Australia. BMJ Open. 2020, 10:e032790. 10.1136/bmjopen-2019-032790
45. Höglinger M, Wirth B, Carlander M, et al.: Impact of a diabetes disease management program on guideline-adherent care, hospitalization risk and health care costs: a propensity score matching study using real-world data. Eur J Health Econ. 2023, 24:469-78. 10.1007/s10198-022-01486-2
46. Moorin RE, Youens D, Preen DB, Harris M, Wright CM: Association between continuity of provider-adjusted regularity of general practitioner contact and unplanned diabetes-related hospitalisation: a data linkage study in New South Wales, Australia, using the 45 and Up Study cohort. BMJ Open. 2019, 9:e027158. 10.1136/bmjopen-2018-027158
47. Wong CK, Wong WC, Wan YF, Chan AK, Chan FW, Lam CL: Effect of a structured diabetes education programme in primary care on hospitalizations and emergency department visits among people with type 2 diabetes mellitus: results from the Patient Empowerment Programme. Diabet Med. 2016, 33:1427-36. 10.1111/dme.12969
48. Zhang J, Donald M, Baxter KA, Ware RS, Burridge L, Russell AW, Jackson CL: Impact of an integrated model of care on potentially preventable hospitalizations for people with type 2 diabetes mellitus. Diabet Med. 2015, 32:872-80. 10.1111/dme.12705
49. van Loenen T, Faber MJ, Westert GP, van den Berg MJ: The impact of primary care organization on avoidable hospital admissions for diabetes in 23 countries. Scand J Prim Health Care. 2016, 34:5-12. 10.3109/02813432.2015.1132883
50. Calderón-Larrañaga A, Soljak M, Cecil E, Valabhji J, Bell D, Prados-Torres A, Majeed A: Does higher quality of primary healthcare reduce hospital admissions for diabetes complications? A national observational study. Diabet Med. 2014, 31:657-65. 10.1111/dme.12413
51. Wolters RJ, Braspenning JC, Wensing M: Impact of primary care on hospital admission rates for diabetes patients: a systematic review. Diabetes Res Clin Pract. 2017, 129:182-96. 10.1016/j.diabres.2017.05.001
52. Gibson OR, Segal L, McDermott RA: A systematic review of evidence on the association between hospitalisation for chronic disease related ambulatory care sensitive conditions and primary health care resourcing. BMC Health Serv Res. 2013, 13:336. 10.1186/1472-6963-13-336
53. Thavam T, Hong M, Devlin RA, Clemens KK, Sarma S: Does financial incentive for diabetes management in the primary care setting reduce avoidable hospitalizations and mortality in high-income countries? A systematic review. Health Policy. 2024, 150:105189. 10.1016/j.healthpol.2024.105189
54. Watson A, McConnell D, Coates V: Reducing unscheduled hospital care for adults with diabetes following a hypoglycaemic event: which community-based interventions are most effective? A systematic review. J Diabetes Metab Disord. 2021, 20:1033-50. 10.1007/s40200-021-00817-z
55. Valentijn PP, Tymchenko L, Gruisen W, Bruls B, Abdalla Pereira F, Arends RY: Effectiveness of integrated care for diabetes mellitus type 2, cardiovascular and chronic respiratory diseases: a systematic review and meta-analysis. Int J Integr Care. 2024, 24:16. 10.5334/ijic.7744
56. Torres Roldan VD, Urtecho M, Nayfeh T, et al.: A systematic review supporting the Endocrine Society guidelines: management of diabetes and high risk of hypoglycemia. J Clin Endocrinol Metab. 2023, 108:592-603. 10.1210/clinem/dgac601