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International Models of Care that Address the Growing Diabetes Prevalence in Developing Countries

Kavita Singh[1,2] · **Harish Ranjani**[3] · **Elizabeth Rhodes**[4] · **Mary Beth Weber**[5]

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Abstract Diabetes care involves a complex interaction between patients, physicians, the health care system, and society. In low- and middle-income countries (LMICs), where the majority of individuals with diabetes live, there is a shortage of resources and infrastructure for diabetes care. Translation of proven interventions for diabetes prevention and care from experimental settings to the real world is a major challenge, and there is limited evidence from LMICs. To curtail the diabetes burden in LMICs, it is crucial to develop and execute innovative diabetes care models that improve access to care, knowledge, and outcomes. Additionally, adequate training of local health professionals and community engagement can help LMICs become self-sufficient in delivery of diabetes care. In this paper, we reviewed the existing models of diabetes care and prevention in LMICs and provided recommendations to guide the development of a comprehensive and effective future model for diabetes care in LMICs.

Keywords Diabetes care models · Prevention · Diabetes management · Low- and middle-income countries · Task shifting · Electronic medical records

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✉ Kavita Singh
kavita@ccdcindia.org

Harish Ranjani
ranjani@mdrf.in

Elizabeth Rhodes
elizabeth.christie.rhodes@emory.edu

Mary Beth Weber
mbweber@emory.edu

[1] Department of Endocrinology & Metabolism, All India Institute of Medical Sciences, Biotechnology Block, 3rd Floor, Ansari Nagar, New Delhi 110 029, India

[2] Centre for Chronic Disease Control, New Delhi, India

[3] Madras Diabetes Research Foundation, 4B Conron Smith Road, Gopalapuram, Chennai 600086, India

[4] Laney Graduate School, Nutrition and Health Sciences, Emory University, 1518 Clifton Road, NE, Atlanta, GA, USA

[5] Hubert Department of Global Health, Emory University, 1518 Clifton Road, NE, Atlanta, GA, USA

Introduction

Three-quarters of the 415 million people living with diabetes worldwide live in low- and middle-income countries (LMICs). By 2040, the number of people with diabetes worldwide is projected to reach 642 million with the largest increases in prevalence in regions with developing economies [1]. Diabetes complications (e.g., retinopathy, blindness, nephropathy, kidney failure, coronary heart disease, and stroke) result in disability, reduced quality of life, and death. The social and economic cost of this epidemic is great, especially in LMICs [2•] where the vast majority of diabetes-related deaths occur [3] and the costs of care place a substantial burden on individuals, families, and health care systems [4]. Productivity losses due to premature morbidity and mortality threaten the economic well-being of families and the economic development of nations [5].

Reducing the burden of diabetes requires both successful prevention efforts and better disease management [6]. Evidence from randomized controlled trials (RCTs) has shown that lifestyle change or glucose lowering drugs can prevent or delay diabetes in high-risk individuals [7–15] and, amongst those with diabetes, good control of risk factors (glucose [16–19], blood pressure, and lipids), avoiding tobacco use [20–24], and proactive use of medications (e.g., aspirin, angiotensin converting enzyme inhibitors) [25] can substantially reduce the incidence and severity of major diabetes complications [23, 26]. Further, it is well established that

multiple risk factor control has the greatest benefits for patients with type 2 diabetes [27–29]. However, many people living with diabetes in developing countries are not receiving the care needed to support optimal risk factor control; diabetes patients in LMICs receive recommended care only about 20–30 % of the time and achieve the recommended targets for glycemia, blood pressure, and cholesterol less than 10 % of the time [30••].

There is a clear need for effective tools and programs to deliver diabetes care within LMICs that account for the multitude of barriers to care that often exist in these settings. Many LMICs, particularly in rural settings, lack the personnel and properly equipped clinics needed to provide specialized care [31, 32]. Additionally, public awareness of diabetes status and management is low, and many clinics and patients cannot afford diabetes treatment [33–36].

Researchers are seeking to address barriers to diabetes care in LMICs by developing and testing new models of diabetes care designed for low-resource health care settings. In this paper, we describe some examples of programs and evaluations underway in LMICs with the aim of identifying gaps in care, challenges in implementation, and strengths and limitations of existing models. In addition, we briefly describe models of diabetes prevention and discuss how to potentially incorporate these programs into diabetes care delivery. We conclude by making recommendations for a model of diabetes care that could be applied in multiple LMIC settings.

Diabetes Care Models in LMIC Settings

Diabetes care models in LMICs fall into three broad categories: personnel-case management, health information technology, and integrated care models.

1. *Personnel–Case Management*

   Over the past 2 decades, the responsibility for the care of people with diabetes has shifted from tertiary care hospitals to primary care clinics. However, many primary care physicians are not trained to provide proper diabetes care, and they may lack the time and resources required to coordinate care for diabetes patients. To overcome these challenges, there is growing focus on building capacity among various program personnel:

   (a) Training care providers: The *Step-By-Step Program* initiated in India and Tanzania focused on preventing lower limb complications in diabetes patients by intensively training physicians and nurses in the use of an algorithm for management of diabetic feet. Training consisted of lectures, practical demonstrations, problem-solving exercises, and hands-on experiences [37, 38]. Three years after program implementation, the percentage of patients with diabetic foot ulcers/complications fell from 24 to 8 %, and the amputation rate fell from 22 to 10 %. Large-scale capacity building initiatives (e.g., certified course on evidence-based diabetes management, diabetes retinopathy, and others) have trained a large number of physicians, diabetes counselors, and other care providers in India (for example, see [39]), but data is not yet available on program impact at the patient level.

   (b) Primary care nurses: Nurse-run chronic disease clinics and team-based care involving physicians, nurses, and dieticians have been used in numerous diabetes programs in Ghana [40], South Africa [41, 42], and Ethiopia [43]. In these programs, primary care nurses diagnosed new patients, made decisions on initial treatment regimens, modified treatment in non complex cases, and referred complex cases to specialists. To further increase ease of diabetes management, 6-month prescription cards were issued to patients with controlled diabetes to decrease the number of clinic visits required. Two years after program roll-out, nurses were able to accurately detect and refer 95 % of cases to specialists and treat 100 % of patients (as per the developed treatment algorithm) that did not require referrals. To date, effectiveness data of these interventions on diabetes care goals are not available.

   (c) Task-shifting/peer for progress model: Several studies and programs have relied on peers (non-professionals familiar with diabetes management), instead of healthcare providers, to assist with diabetes case management and long-term self-care of diabetes patients with an aim to reduce cost of care. The short-term impact of these "peers for progress" models on risk factor control has been evaluated across several countries (Cameroon, Uganda, South Africa, and Thailand). In these programs, peer supporters received training to address the issues of diet, exercise, coping with stress, and diabetes self-management and was assigned a group of patients (10–20) with whom they met regularly. Participants showed improvements in markers of weight and blood pressure and at each site except South Africa, mean glycated hemoglobin (HbA1c) declined significantly [44].

2. *Health Information Technology*

   An electronic automated monitoring and self-care support tool to improve diabetes care was tested for its effectiveness in Honduras and Mexico [45]. Patients with diabetes received weekly automated monitoring and self-care support calls on their cell phones where patients reported health and self-care problems. Clinicians and family caregivers received automatic alerts with patient updates and suggestions for supporting the patient's success in

diabetes management. At 6 weeks, 92 % of patients were engaging regularly with the automated mobile health support and reported greater satisfaction with their health care, fewer depressive symptoms, fewer medication use problems, and higher levels of overall perceived health.

3. *Multicomponent and Integrated Care*

Increasingly, programs that integrate several diabetes care components are being implemented and evaluated in LMICs. For example, the CARRS Trial tested the clinical effectiveness and sustainability of a low-cost multicomponent diabetes care model in South Asia [46]. Poorly controlled, type 2 diabetes patients ($n = 1146$) were assigned to usual care or a multicomponent quality improvement strategy consisting of non-physician care coordinators and electronic health records with decision-support software (EHR-DSS). The intervention focused on improving patient self-care and facilitating better monitoring and treatment intensification by providers. At 28 months, twice as many intervention as usual care participants (17.7 vs. 7.5 %; $p < 0.001$) achieved the primary outcome of multiple risk factor control (HbA1c < 7 % and either blood pressure < 130/80 mmHg or LDLc < 100 mg/dl), and intervention participants reported significantly higher quality of life and treatment satisfaction.

The Chunampet Rural Diabetes Prevention Project (CRDPP) was established in rural India to provide holistic diabetes care and promote diabetes prevention through the use of telemedicine [47]. This project used a mobile healthcare van equipped with a digital retinal camera, electrocardiography (ECG), Doppler, biothesiometry, and a satellite to communicate with an urban diabetes care center to screen for the complications of diabetes. Village health workers, trained individuals with basic high school qualifications, promoted screening for complications [47, 48]. This program screened 86.5 % of the adult population in and around the 42 villages of Chunampet and identified 1138 individuals with diabetes and 3410 with prediabetes. The mean HbA1c levels among the subjects with diabetes in the community decreased from 9.3 ± 2.6 to 8.5 ± 2.4 % within a year of implementing this project. Less than 5 % of patients needed referral for further management to the tertiary diabetes hospital in Chennai [48].

An initiative in Malawi adapted the directly observed therapy, short course (DOTS) model for Tuberculosis treatment and developed the *DOTS for diabetes model* [49]. The intervention consisted of care delivery through trained nurses using standardized diabetes treatment guidelines (quarterly clinic visits with more frequent visits when diabetes was poorly controlled and annual screening for microalbuminuria and retinopathy) and increasing the supply of diabetes drugs. To maintain patient records and facilitate data analysis, an Electronic Medical Records (EMR) was developed. Patients were given a "health passport" that contained barcodes for rapid access to patients' EMRs. Clinic visit summaries, prescriptions, appointment dates, and other important medical information were printed into patient passports. At 1 year, 1864 patients were registered, but no outcome data is currently available to assess the effectiveness of the program.

In Costa Rica, a small-scale RCT of 75 patients with diabetes tested the effects of a community-based nutrition and exercise program versus basic diabetes education only [50]. This study reported significant improvement in weight (−1 vs. −0.4; $p = 0.028$), fasting glucose levels (−19 vs. +16; $p = 0.048$), and HbA1c (−1.8 vs. −0.4; $p = 0.028$) in the intervention group compared to the control group. In another RCT of 150 patients with diabetes in Shanghai, China, an *integrated intervention program* consisting of in-depth diabetes education focused on frequent clinic visits and blood glucose monitoring, nutrition counseling, and meal plans (intervention group) was compared to basic diabetes education (control group). At 12 weeks, the intervention group had significantly lowered their fasting blood glucose, systolic and diastolic blood pressures, HbA1c, and waist-to-hip ratio relative to the control group [51].

Diabetes Prevention Models

The importance of prevention for curbing the diabetes epidemic has long been recognized; however, models for diabetes prevention in LMICs are underdeveloped, limiting progress in preventing diabetes in these settings. Lifestyle interventions have been shown to have significant and sustained benefits for individuals at high-risk for diabetes in high-income countries. For instance, the US Diabetes Prevention Program (DPP) trial showed that participants enrolled in a lifestyle intervention reduced their risk of developing diabetes by 58 % compared to controls [7], and a review of 28 US-based studies implementing the DPP concluded that people at high risk for diabetes can achieve clinically significant weight reduction in real-world settings [52]. Adapting and implementing the DPP or other proven diabetes prevention programs in LMICs can be effective for diabetes prevention in high-risk populations; however, these programs need to be cost-effective, culturally appropriate, and address regional barriers to diabetes prevention (e.g., access to medical care, views of physical activity, food availability) [53].

The data on diabetes prevention in LMICs is limited compared to high-income countries, but there is evidence of some successes. Early efforts in China and India focused on conducting large RCTs of lifestyle intervention for diabetes prevention among individuals with impaired glucose tolerance (IGT). Results from both studies showed substantial reductions in diabetes incidence among lifestyle intervention

participants compared to controls (relative risk reduction = exercise alone 41.1 %, diet alone 43.8 %, and diet + exercise 46 % in the Da Qing IGT and Diabetes Study [15] and 28.5 % in the Indian Diabetes Prevention Programme [12]). These efficacy studies demonstrated that diabetes prevention efforts were possible in lower-resource settings, but they did not attempt to address LMIC-specific barriers to care.

More recent studies have tested different methodologies for overcoming barriers to delivering lifestyle interventions, such as cost, access to at-risk individuals, and health provider shortages. For example, the Indian Diabetes Prevention Programme-3 randomized participants at ten worksites in India to receive either standard lifestyle advice (controls) or a lifestyle intervention delivered by mobile phones. This study reported a significant reduction in diabetes incidence among intervention participants compared to controls (hazard ratio 0.64, 95 % confidence interval [CI] 0.45–0.92). These results showed that a lower-cost intervention could be beneficial for diabetes prevention and utilizing mobile phones may be a promising strategy for delivering lifestyle advice to hard-to-reach populations [54].

Other studies are testing the delivery of diabetes prevention to a broader at-risk population with the goal of preventing disease in the largest number of individuals. To date, the vast majority of prevention efforts have targeted adults at high-risk for developing diabetes, but this conventional approach may not be sufficient for slowing the diabetes epidemic, particularly in populations (e.g., South Asians) which display a rapid conversion from prediabetes to diabetes [29]. For example, the DIABRISK-SL [55] RCT in Sri Lanka aims to compare an intensive (3 months) lifestyle modification advice to a less-intensive (12 monthly; control group) lifestyle modification advice on a primary composite cardio-metabolic endpoint, in at-risk (two or more of the following: obesity, elevated waist circumference, family history of diabetes, or physically inactive) urban subjects aged between 5 and 40 years. Early results indicate a 26 % (95 % CI 7–28 %) relative risk reduction in diabetes incidence among participants in the intensive lifestyle intervention compared to the less-intensive intervention [56]. Similarly, the Diabetes Community Lifestyle Improvement Program (D-CLIP) [57] was a RCT of diabetes prevention in adults with any form of prediabetes (IGT, impaired fasting glucose or both) comparing standard of care to a culturally tailored lifestyle education curriculum based on the DPP plus stepwise addition of metformin when needed. Each lifestyle class was paired with a community volunteer peer educator, and participants were divided into peer support groups to increase social support for lifestyle change and improve sustainability of the program. After 3 years of follow-up, the relative risk reduction for diabetes was 32 % (95 % CI 7–50) comparing lifestyle participants to controls [58].

Other studies have relied on trained peer educators to deliver diabetes prevention messages as a way to lower the cost of diabetes prevention. Studies in Thailand [59, 60] reported improvements in health promotion behaviors, diabetes risk factors (markers of adiposity, blood pressure), and diabetes prevention knowledge among individuals who participated in peer-led prediabetes screening or diabetes prevention programs. These results are consistent with the findings from a meta-analysis of translational research studies of the DPP in the US, which found that lay educators can be as effective as health professionals in delivering lifestyle education [52].

Finally, there is a need for cost-effective ways to identify individuals at-risk of developing diabetes and its complications. Existing screening tools like HbA1c testing or oral glucose tolerance tests can be cost-prohibitive or unavailable due to lack of necessary reagents or testing equipment in low-resource settings. One study in Colombia showed that the use of a non-invasive, easy to administer risk-assessment tool (FINDRISC) could be used to identify individuals who have a high risk of diabetes and could benefit from diabetes prevention [61]. Other risk scores (e.g., the Indian Diabetes Risk Score [MDRF–IDRS] [62]) have been shown in other settings to be similarly effective and cost-effective tools for screening.

Discussion

The models of diabetes care implemented and tested in LMIC settings often focus on quality improvement and fall into one of three categories: (1) *non-physician personnel/case management*—coordinating diagnosis, treatment, or ongoing patient management (e.g., arrangement for referrals, follow-up of clinic visits, and test results) by a trained health personnel or multidisciplinary team; (2) *health information technology*—electronic medical records (EMR) or electronic tracking system for patients with diabetes; and (3) *multicomponent models and integrated care packages*—initiatives that combine one or more diabetes care interventions to deliver an integrated package of care.

Although there is only limited evaluation data, some components seem particularly promising. The use of standardized practical clinical protocols optimizes existing resources and makes convenient and effective treatment feasible [38, 49]. The implementation of standardized guidelines and treatment algorithms has the potential to vastly improve medical care by informing health care professionals what is expected of them and ensuring more reproducible care of patients by different health care workers [40, 63, 64]. Another key element of diabetes care in low-resource settings is task shifting to reduce the burden on a limited physician workforce [44, 64, 65]. While some programs [42, 43] improved patient care and access by taking advantage of the established health care system and placing nurses at the center of chronic diabetes care, others [44, 46] trained non-physician care coordinators as care managers. The fact that community volunteers were readily available to participate as peers indicates the presence of a valuable resource; individuals living in underserved communities will often be willing

to aid in the delivery of care to their neighbors and friends if they are properly educated on how to do so [44, 66].

Similarly, proven diabetes prevention models are increasingly being adapted for delivery in low-resource settings. One method for improving the uptake of diabetes prevention by clinics or communities might be to integrate diabetes prevention programs into diabetes care. For example, lifestyle modification has been shown to be effective not only for diabetes prevention but also for diabetes care [67, 68], and classes and programs could be designed to reach both of these populations simultaneously. Similarly, mobile phone messaging programs could be tweaked to provide tailored messages to individuals with or at risk for diabetes with only minimal additional resources.

Gaps and Challenges in Diabetes Care

Many factors affect the outcomes of diabetes care. The barriers identified in the implementation of diabetes care programs/models have been poor laboratory facilities, high rates of hospital staff turnover, clinic staff shortages, high costs of delivering care, lack of administrative support, and lack of egalitarianism within health care delivery teams [69]. Many other factors influence the success of treatment outcomes in diabetes such as patient's non-adherence to prescribed treatment, the failure of physicians to intensify therapy in a timely manner, and inadequacies in the health care system itself (Table 1) [70]. However, the newer therapies and devices, combined with a comprehensive diabetes care model involving adequate patient education, can help minimize barriers and improve treatment outcomes [70].

Recommendations for a Comprehensive Diabetes Care Model/Program in LMICs

A comprehensive diabetes care model for LMICs could help reduce the growing burden of diabetes and support diabetes patients in achieving their treatment goals by improving the efficiency of the healthcare system, increasing access to care, and addressing patient issues and diabetes-related complications. Existing literature supports improved physician and nurse education and increasing the role of trained community health care workers and non-physician care coordinators for facilitating diabetes care. In addition, an organized multidisciplinary team is required to successfully deliver the care model and prevent clinical inertia, i.e., to enhance physician's responsiveness to treatment intensification. While new advances in diabetes therapy may help patients to achieve their HbA1C goals, patient education plays a fundamental role in minimizing the barriers to optimal glycemic control and should form a core component of a comprehensive diabetes care model [71, 72].

The broader agenda of such a model for LMICs should include the following:

1. Determination of high at-risk groups in the general population using diabetes risk scores or other low-cost, low-burden tools [73]
2. Early diagnosis and treatment of diabetes [74] using low cost screening tools and promoting healthy lifestyle behavior through peer-support models or community health workers to reduce the cost burden for patients and health system
3. Recognition and treatment of acute complications (severe hypoglycemia and diabetic ketoacidosis) [75, 76]
4. Prevention of chronic complications (diabetic retinopathy, diabetic foot, kidney, and cardiovascular diseases) [77]
5. Increasing health literacy of patients and their families to foster better self-care [71]
6. Enhancement of patient's quality of life and rehabilitation of patients with partial or total working disability by innovative approaches to equip community health centers to provide rehabilitation services

Based on these broader critical issues and taking lessons from the existing prevention and care models, we propose an integrated four-level diabetes care model: (a) community awareness and population-level diabetes prevention, (b) prevention and early diagnosis in people at high risk of diabetes, (c) optimal initial and long-term management in newly diagnosed diabetes, and (d) early detection and optimal management of diabetes complications (Fig. 1).

Table 1 Factors affecting treatment outcome success

Health system-level factors	Physician-level factors	Patient-level factors
Lack of visit planning	Insufficient time	Cost of treatment
Lack of follow-up	Failure to initiate	Medication side effects
Lack of team coordination	Failure to titrate goal	Complex care regimens
Lack of decision-support	Concern of causing harm	Forgetfulness
Fragmented healthcare system	Failure to identify and manage comorbidities	Absence of symptoms
Nonavailability of drugs	Underestimate patient need	Poor health literacy
No insurance coverage		Lifestyle/cultural factors

Adapted from Ross [70]

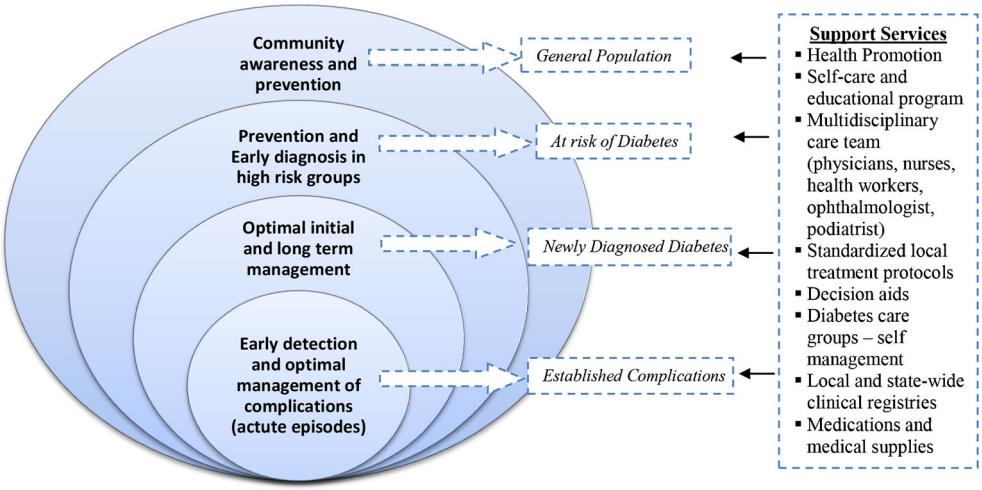

Fig. 1 Comprehensive diabetes model of care—proposed schematic diagram

Community awareness and prevention of diabetes in the population require maintaining healthy environment and lifestyle. This can be achieved through increasing government-backed schemes/subsidies for healthy foods, increasing the number of health stores, growing fruits and vegetables in kitchen garden, and building opens spaces for physical activity. In addition, localized and standardized diabetes awareness programs in collaboration with a national level program can be implemented. At a higher level, the local governments, NGO's, community groups, employers, and the food industry could collaborate and work in tandem to ensure that people live in an environment that supports and encourages healthy lifestyles.

Prevention and early diagnosis in high-risk groups necessitate awareness of risk factors for diabetes and an understanding of the importance of early diagnosis, self-management, and treatment for prevention of long-term complications. This can be achieved by undertaking community-wide and targeted health promotion activities and developing appropriate information resources; e.g., lay health workers can be involved in promoting awareness of diabetes self-management and initial risk screening. At a higher level, a multidisciplinary group should collate, develop, distribute, promote, and audit evidence-based risk assessment and early diagnosis protocols to physicians and other health professionals to ensure comprehensive identification of people at high risk of diabetes. Additionally, national steering committees should be formed to approve guidelines for diabetes care and dietary recommendations by adapting to international guidelines to local settings. Local diabetes care groups, non-physician care coordinators, and peer educators can play a crucial role by improving local coordination, accessibility, and effectiveness of health promotion services and diabetes prevention activities.

Furthermore, the national program for diabetes prevention and management can promote *optimal initial and long-term management* through accessible, local-level, community diabetes services with streamlined referral processes and local resources directories. In partnership with NGOs, local government should promote smoke-free environments and ensure that affordable smoking cessation programs are available for diabetes patients. Audits of diabetes services and workforce should be conducted to determine the nature and capacity of diabetes services available and to help health care facilities identify service gaps.

To encourage *early detection and optimal management of complications*, care providers need to ensure that all people with diabetes are knowledgeable about diabetes complications and their prevention and the need for regular assessment for early detection. Multidisciplinary advisory panels can be created to collate, develop, distribute, promote, and regularly update evidence-based, national guidelines for systematic early detection and management of diabetic complications.

Finally, to ensure timely, effective communication between health professionals and other care providers and transitions of patient care from acute to primary and community care settings, liaison, triage, and IT systems are needed. To streamline the process of patient referral systems and improve communication, coordination, and data sharing between physicians and other providers, a patient-centered electronic information system is needed [78, 79]. The local governments can allocate regional responsibilities to specific tertiary and secondary care centers to ensure that all metropolitan and regional primary health care providers have ready access to specialist multidisciplinary teams for advice, shared care, outreach, and mobile health services.

Research Opportunities

There is an acute need for more research into effective models of diabetes care and prevention in LMIC settings. Many of the studies presented here are in process or lack program evaluation, and thus dissemination of these programs is not justified. Furthermore, while many of the studies reported results demonstrating broad, directional changes, it would have been more

informative if specific outcome measures had been tested and included in every publication (for example improvements in HbA1c, incidence of diabetes complications, and patient behaviors including medication adherence and self-care measures). Additionally, we need follow-up publications that describe program cost, cost-effectiveness, and sustainability. Finally, other innovative strategies, such as community pharmacy-based services [80] and mHealth tools [81] to overcome barriers to adherence/self-care, are currently being evaluated and may provide promising avenues for improving diabetes care.

Conclusions

Diabetes care involves a complex interaction between patients, physicians, the health care system, and society. Translation of proven interventions from experimental to real world settings occurs at every level. Thus, the development and implementation of innovative diabetes care models in LMICs that address improving the health literacy of the public, increasing access to care, adequately training local health care professionals, and facilitating community engagement will help LMICs become self- sufficient in delivery of diabetes care. In fact, such models might prove to be the impetus that changes the method to deliver and receive medical care in LMICs. The principles of collaboration, education and training, standardization of treatment guidelines, task shifting, and technological innovation as evident in the reviewed models might guide the growing wave of involvement in diabetes care across the globe.

Compliance with Ethical Standards

Conflict of Interest Kavita Singh, Harish Ranjani, Elizabeth Rhodes, and Mary Beth Weber declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- •• Of major importance

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