Annals of Global Health
Published by Elsevier Inc. on behalf of Icahn School of Medicine at Mount Sinai.
VOL. 83, NO. 3–4, 2017
ISSN 2214-9996/$36.00
https://doi.org/10.1016/j.aogh.2017.10.009

STATE OF THE ART REVIEW

Community Health Workers in Diabetes Prevention and Management in Developing Countries

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Abstract

BACKGROUND There is limited evidence regarding the effect of community health worker (CHW) interventions for prevention and management of the burgeoning epidemic of noncommunicable diseases (NCDs) in low- and middle-income countries (LMICs). The objective of this review was to critically appraise evidence regarding the effectiveness of CHW interventions for prevention and management of type 2 diabetes mellitus (T2DM) in LMICs.

METHODS To identify studies that reported the effect of CHW interventions for prevention and management of T2DM in LMICs, Medline/PubMed, EMBASE, Web of Science (Science and Social Science Citation Indices), EBSCO (PsycINFO and CINAHL), POPLINE, the Cochrane Metabolic and Endocrine Disorders Group's Specialized Register, the Cochrane Central Register of Controlled Trials, the Grey literature (Google, Google Scholar), and reference lists of identified articles were searched from inception to May 31, 2017.

FINDINGS Ten studies were included (4 pre- and post-studies, 2 randomized controlled trials, 2 cohort studies, 1 cross-sectional study, and 1 case-control study). The role of CHWs consisted of patient education, identification and referral of high-risk individuals to physicians, and provision of social support through home visits. Positive outcomes were reported in 7 of 10 studies. These outcomes included increased knowledge of T2DM symptoms and prevention measures; increased adoption of treatment-seeking and prevention measures; increased medication adherence; and improved fasting blood sugar, glycated hemoglobin, and body mass index. Three studies showed no significant outcomes.

CONCLUSIONS CHWs have the potential to improve knowledge, health behavior, and health outcomes related to prevention and management of T2DM in LMICs. Given the limited number of studies included in this review, robust conclusions cannot be drawn at the present time.

KEY WORDS community health worker; diabetes; diabetes management; diabetes prevention; low-and middle-income countries

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INTRODUCTION

Noncommunicable diseases (NCDs) pose a high priority threat to public health worldwide. In 2013, the World Health Assembly adopted the Global NCD Action Plan, specifying 9 global targets and a monitoring framework for preventing and controlling NCDs by 2020.[1] Likewise, the Sustainable Development

Conflicts of Interest: All authors state that they have no conflict of interest.
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Goals established by the United Nations recognize the importance of reducing global NCDs.[2] The Global Status Report on NCDs emphasizes that the negative impacts of NCDs are particularly severe in poor and vulnerable populations, where poverty exacerbates many health conditions. Over three-quarters of the global NCD deaths (28 million) and the majority of premature deaths (82%) occur in low- and middle-income countries (LMICs).[1]

Among global NCDs, type 2 diabetes mellitus (T2DM) is especially common.[3,4] The International Diabetes Federation recently reported that the incidence of diabetes will increase from 415 million in 2015 to 642 million by 2040, with more than 70% of the cases in LMICs.[5] Despite numerous initiatives to prevent diabetes and diabetes-related complications,[6,7] the disease remains the fourth leading cause of disease-related deaths globally, with almost 80% occurring in LMICs.[1] In 2010, LMICs were estimated to have spent >5% of their health expenditures on diabetes.[8] These estimates did not include undiagnosed T2DM cases, which, in LMICs, account for over 50% of people with T2DM.[9] In addition, indirect diabetes-related costs arising from lost productivity due to disability, premature mortality, and absenteeism could reach US$13 billion annually for a LMIC.[10]

Although many cost-effective interventions address diabetes,[11] LMICs experience multiple barriers to adequate diabetes management.[12,13] Weak national health systems make it difficult to deliver sustainable, equitable, and effective interventions.[14] In many LMICs, there are critical shortages of health care workers, since current medical schools cannot keep up with increasing demand for health care services, internal and external migration of health workers, low workforce productivity, and population growth.[15,16] In addition, patient education—an inexpensive and effective diabetes-management option—is not practiced routinely.[9,17,18] Finally, LMIC guidelines and national priorities have historically focused on infectious diseases.[19] These limitations represent a need for paraprofessional health workers, who can bring diabetes prevention and management practices to their communities.

Community health workers (CHWs) have received renewed attention as a means of strengthening primary health care systems and achieving global health goals.[20-23] CHWs serve as bridges among their ethnic, cultural, or geographic communities and health care providers.[24,25] They increase knowledge and self-sufficiency through outreach, community education, informal counseling, social support, and advocacy. CHWs are uniquely positioned to collaborate with diabetes educators and other health care providers. In chronic disease care, CHWs often educate patients, identify resources, provide case management, coordinate care with the health care system, and become part of people's support networks.[26] As community members, CHWs instill ownership of health problems, foster trust, and facilitate the assimilation of medical innovations; they also reduce per capita demand for health care providers. Finally, they provide relatively inexpensive solutions to the growing strain on the health care workforce.[27,28] Therefore, the prospective impact of CHWs in mitigating disease burden in LMICs is tremendous.

CHWs in LMICs have been invaluable in managing maternal and child health services and infectious diseases such as malaria, tuberculosis, and sexually transmitted infections.[21,29-31] In high-income countries, CHW-led interventions have also improved health behaviors and outcomes, particularly for racial/ethnic minorities and individuals without adequate healthcare.[32-36] However, little is known about the effectiveness of this approach in LMICs. The only recent review by Jeet et al[37] on CHW interventions for NCD prevention and control in LMICS had several limitations that our review sought to address. First, their review included only randomized control trials, which typically do not cover the full spectrum of evidence for intervention effectiveness in LMICs where scarcity of resources often makes such studies impracticable. Second, the six studies[38-43] identified as CHW-led diabetes interventions by Jeet et al[37] did not meet our strict inclusion criteria.

Specifically, the study by DePue et al[38] was a nurse-CHW initiative. Nurses are not CHWs, and DePue et al[38] did not separate the effect of nurse intervention from that of CHWs; neither could they have been able to do so. It was unclear how CHWs were defined in the review. Zhong et al[39] was a peer-support intervention and not strictly a CHW intervention, and the intervention included initiatives in both primary care clinics and community settings. The study by Jafar et al[40] focused on blood pressure (BP) but was referenced as a diabetes intervention in the table of characteristics of studies, and that by Thankappan et al[41] was about smoking cessation among diabetic patients but was referenced as a diabetes prevention intervention. The Wattana et al[42] study assessed the effects of a diabetes self-management program on glycemic control. The intervention was conducted in community hospitals, but there was no indication that it was delivered by CHWs. Thus, a huge gap still remains in knowledge regarding the impact of CHW

interventions on prevention and management of T2DM, a major cause of morbidity in LMICs. Finally, in the study by Goldhaber-Fiebert et al,[43] the nutrition classes were taught by 3 nutritionists who were enrolled in a master's degree program in nutrition at University of San Jose, and local volunteer community leaders organized and led the walking groups. There was no mention of a role for CHWs in this study. Therefore, the goal of this systematic review was to critically review the effectiveness of such interventions for T2DM in LMICs. A comprehensive review of the current knowledge base will facilitate the planning of evidence-based programs and help focus future research.

METHODS

Definition of Terms. The *community health worker* construct has no universally accepted definition or role. The literature usually refers to CHWs as trusted community members who promote access to health care by providing health education, basic medical care, or referrals to doctors and nurses.[44] As shown in Table 1, CHWs are known by a variety of names, including but not limited to lay health advisors, community health representatives, community health advisors, voluntary health workers, health promoter/promoters, patient navigators, peer counselors, peer health advisors, and public health aides.[45,46] This study focused on the role of CHWs in preventing and managing T2DM. Because the current diabetes epidemic is attributable predominantly to rising cases of T2DM in LMICs,[9] only T2DM was considered in this review.

Low-income countries have gross national incomes per capita of $1045 or less as of 2014.

Middle-income countries have gross national incomes per capita of at least $1045 but less than $12,736.[46]

Primary prevention seeks to prevent specific diseases by altering behaviors around or exposure to disease agents or by enhancing resistance to the effects of exposure. Primary prevention generally targets specific causes and risk factors and may aim to promote healthy behaviors or foster risk-free environments.

Secondary prevention includes procedures that detect and treat preclinical pathological changes to control disease progression.

Tertiary prevention aims at reducing complications among individuals with symptomatic or advanced disease.[47]

Search Strategy. To identify relevant studies, the following databases were searched from inception to May 31, 2017: Medline/PubMed, EMBASE, Web of Science (Science and Social Science Citation Indices), EBSCO (PsycINFO and CINAHL), POPLINE, the Cochrane Metabolic and Endocrine Disorders Group's Specialized Register, the Cochrane Central Register of Controlled Trials, and the Grey literature (Google, Google Scholar). In addition, we handsearched reference lists of identified articles and contacted investigators and organizations whose research or programs relate to community prevention and management of diabetes. A broad range of search terms that focused on CHWs and prevention and management of diabetes was used to search each database. These terms (Table 1) were adapted from Gilmore and McAuliffe[48] and further refined by the research team and a public health librarian to account for varying terminologies used to describe CHWs in different countries, broad location of studies, and different references to T2DM.

Inclusion Criteria.

Types of Study. Randomized controlled studies, cross-sectional studies, cohort studies, controlled before-and-after studies, and case-control studies that assessed the effect of any CHW-led intervention for T2DM prevention and management. The search was not restricted by language, sample size, or duration of intervention, and covered studies published from inception to May 31, 2017.

Study Population. Individuals with T2DM who were exposed to CHW-led interventions to prevent or manage T2DM. We applied the World Bank's 2016 classification of world economy criteria to identify countries that fall within the LMIC category.[46]

Types of Intervention. T2DM care or prevention intervention (primary, secondary, or tertiary) provided by CHWs in homes, communities, or other non-hospital settings.

Type of Control. No CHW-led T2DM intervention.

Types of Outcome. Because different interventions may target one or multiple behavioral or health outcome measures, the review placed no restrictions on outcomes that might result from CHW-led T2DM care or prevention interventions.

Exclusion Criteria. We used Gilmore and McAuliffe's[48] criteria to exclude studies that exhibited the following characteristics: 1) did not meet the above stated inclusion criteria, 2) intervention was unclear, 3) multiple interventions made it impossible to identify and separate specific CHW T2DM intervention outcomes, 4) description of CHWs was unclear, 5) role of CHWs in intervention delivery was not specified clearly, or 6) intervention was delivered at least in part by other cadres of health providers. Application of inclusion and exclusion criteria was conducted by three reviewers (IA, HA, and JE).

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Table 1. Search Strategy for Identification of Studies

1. "Community Health Workers" OR "Community Health Work*"
2. "CHWs"
3. "Community near2 Health Work*"
4. "Lay Health Work*" OR Lay near2 Health Work*" OR "LHWs"
5. "Village Health Work* OR "VHW" OR "Village near2 Health Work*"
6. "Voluntary Health Work* OR "VHW" OR "Voluntary near2 Health Work*"
7. "Health Auxiliary" OR "Auxiliary Health Work*"
8. "Health Visitor" OR "Health Extension Work*"
9. "Lady Health Work*"
10. "Activista"
11. "Accredited Social Health Activist"
12. "ASHA workers"
13. "Anganwadi"
14. "Barefoot doctor"
15. "Basic health workers"
16. "Brigadista, Colaborador voluntario"
17. "Community assistants"
18. "Community health agents"
19. "Community health assist*"
20. "Community health promot*"
21. "Community health represent*"
22. Community health support"
23. "Community health surveyor"
24. "Community health distributor"
25. "Community health volunteers"
26. "Community mobilizers"
27. "Community nutrition workers"
28. "Community resource person*"
29. "Community support workers"
30. "Community volunteers"
31. "Female community health volunteers"
32. "Female multipurpose health Workers"
33. "Health advisors" OR "Health and nutrition workers" OR "Health promot*" OR "Home health aides" OR "indigenous health workers" OR "kader workers" OR "Lady health workers" OR "Lay Health Work* OR "Lay volunteers" OR "Link work*" OR "Outreach educat*" OR "Paramedical work*" OR "Peer health advisors" OR "Peer advisers" OR "Peer volunteers" OR "Peer support*", "Promotora*" OR "Promotoras de salud" OR "Rural health motivator" OR "Rural Health Workers" OR "Shastho shebika" OR "Shasthyo shebika" OR "Shastho karmis" OR "Sevika" OR "Tecnicos" OR "Técnicos de cirurgia" OR "Village drug-kit manager" OR "Village health helpers" OR "Village health workers" OR "Voluntary workers"
34. "Develop* OR "low-income" OR "middle-income" OR "resource poor" OR "global south" OR "third world"
35. Lay OR voluntary OR volunteer* OR untrained OR unlicensed OR nonprofessional* OR "non-professional*" OR "visitor*" OR "attendant*" OR "aide" OR "aides" OR "support*" OR "helper*" OR "carer* OR "caregiver*" OR "assistant*"
36. "Allied health personnel" OR "allied health work*" OR "support work*" OR "home health aide"
37. "Prevent*" OR "Control" OR "Manage*" OR "deterren*" OR "education" OR "teach*" OR "promot*" OR "counsel*" OR "advise" OR "outreach" OR "health promot*" OR "health educat*" OR "disease prevent*" OR "illness prevent*")
38. ((#1-38) AND "prediabet*" OR "diabet*", OR "insulin resist*", OR "diabetes mellitus", OR "diabetes insipidus", OR "endocrine*", OR "insulin", OR "juvenile diabet*", OR "type 2 diabetes mellitus" OR, type 2 diabet*)
39. ("Trained" OR "unlicensed" near2 volunteer* OR "health worker" OR mother* OR "community member") AND (Prediabet* diabet*, insulin resist*, diabetes mellitus, diabetes insipidus, endocrine*, insulin, juvenile diabet*, type 2 diabetes mellitus, type 2 diabet* OR
40. ("Community" OR "health") near2 ("volunteer" OR "aide" OR "support" OR "extension" OR "assistant" OR "auxiliary") AND (prediabet* diabet*, insulin resist*, diabetes mellitus, diabetes insipidus, endocrine*, insulin, juvenile diabet*, type 2 diabetes mellitus, type 2 diabet*)

Study Selection. Two reviewers (IA and HA) independently screened titles and abstracts of identified studies to assess eligibility for inclusion. Where there were uncertainties regarding eligibility, all reviewers participated in the decision about inclusion.

Study Quality Assessment. The quality of included studies was assessed using the procedures described by Li et al.[49] Specifically, case-control and cohort studies were assessed using the Newcastle Ottawa Scale.[49] For case-control studies, we assessed the adequacy of case and control definition, case representativeness, homogeneity of control and case populations, comparability of cases and controls in study design and analyses, and ascertainment of exposure and nonresponse rates. For cohort studies, we assessed the representativeness of the exposed cohort in the study setting, selection of nonexposed cohort, ascertainment of exposure, demonstration that outcome of interest was not present at start of study, comparability of cohorts on the basis of design and analyses, and adequacy of outcome assessment and follow-up.[50] For cross-sectional studies, we used the guidelines for critical appraisal developed by the National Collaborating Center for Environmental Health.[51] We assessed representativeness of study participants; methods of ascertaining exposure; comparability of exposure groups (including unexposed) in terms of age, sex, and socioeconomic status; nonresponse bias; determination and validation of outcomes; internal validity; and assessment and handling of confounding factors. For pre- and post-test studies, we used the quality criteria developed by the Heart, Lung and Blood Institute (HLBI) of the US National Institutes of Health.[52] Specifically, we assessed whether:

- study questions or objectives were clearly stated;
- eligibility/selection criteria for the study population were pre-specified and clearly described;
- participants in the study were representative of those who would be eligible for the test/service/intervention in the population of interest;
- all eligible participants that met the pre-specified entry criteria were enrolled;
- sample size was sufficiently large to provide confidence in the findings;
- intervention was clearly described and delivered consistently across the study population;
- outcome measures were pre-specified, clearly defined, valid, reliable, and assessed consistently across all study participants;
- outcome measures of interest were taken multiple times before the intervention and multiple times after the intervention;
- people assessing the outcomes were blinded to the participants' exposures/interventions.
- losses to follow-up after baseline were 20% or less;
- those lost to follow-up were accounted for in the analysis;
- statistical methods examined changes in outcome measures from before to after the intervention;
- statistical tests were performed to provide *P* values for the pre-to-post changes;
- statistical analysis took into account the use of individual-level data to determine effects at the group level;
- intervention was conducted at a group level.

After reviewing the quality of each included nonrandomized controlled study on basis of these criteria, we assigned a composite quality score that ranged from 0 (low) to 9 (high).

We assessed the quality of randomized controlled trials using the dimensions of methodological quality described by Schulz.[53] We assessed whether the risk of bias was high, low, or unclear for the following quality criteria:

- generation of allocation sequence (we assessed the method used to assign participants to study groups);
- concealment of allocation (because there is evidence that the quality of allocation concealment particularly affects the results of studies,[53] we assessed whether there is evidence that the authors took proper measures to conceal allocation through, for example, centralized randomization or use of serially numbered, opaque, sealed envelopes);
- blinding (we assessed whether the study was double-blind, single-blind, or open);
- data analysis (we assessed losses to follow-up, whether all randomized participants were included in the analysis, and whether the authors adjusted for clustering in their analysis);
- risk of contamination (we assessed whether participants were exposed to nonintervention-related programs; three reviewers [JE, IA, and HA] assessed study quality).

Data Extraction. Data from eligible studies were independently abstracted by two reviewers (IA and HA). Differences were resolved by consensus among all reviewers. Studies were stratified by design (randomized controlled trial, cohort, cross-sectional, and case-control). For case-control studies, information about size of cases and controls was extracted, including number of cases and controls exposed and unexposed to CHW intervention. For cohort studies, numbers of participants and numbers of incident cases with health outcomes of interest in exposed and unexposed individuals with T2DM were extracted. For cross-sectional studies, data on number of persons in study groups and number of persons exposed and

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unexposed to health outcomes of interest were extracted from comparison groups. We also extracted data on sample size, age, and data-collection methods. This systematic review was assessed and approved as exempt by the Institutional Review Board of the University of Arizona.

Data Analysis. We did not conduct statistical meta-analyses, given that very few studies qualified for inclusion. More importantly, there was marked heterogeneity in the design and methodology of the included studies, and most did not provide appropriate statistical data to permit meta-analysis or tests of heterogeneity. Thus, we conducted a systematic review of the 10 eligible studies by summarizing, comparing, and contrasting the extracted data. The following section presents the results of our review.

RESULTS

Description of Included Studies. As shown in Figure 1, we included 10 eligible studies conducted in Asia (Thailand,[54] Iran,[55] and India[56-58]), North and South America (Jamaica,[59] Brazil,[60] and Guatemala[61]), and Africa (South Africa[62,63]). These studies were published between 2010 and 2015 and included 4 pre-post,[54-56,58,61] 2 randomized controlled trials,[60,63] 2 cohorts,[57,59] 1 cross-sectional,[55] and 1 case study[62] (Tables 2 and 3). All identified studies were published in English. Intervention settings spanned urban and rural health centers, community centers, and homes. A variety of strategies was used to recruit participants: selection by researchers, clinic charts, provider, or advertising. Identified studies fell under two major categories: those that assessed the effect of CHW on prevention of T2DM development and those that assessed the effect of CHW intervention on preventing T2DM-associated complications. Study quality assessment showed that three of the included studies—(Farzadfar et al[55] (cross-sectional), Less et al[59] (cohort), and Ndou et al[62] (case control)—were of good quality (score of 5 or higher). The 2 randomized control trials included in the review, Souza et al[60] and Mash et al,[63] failed to report on the assessed quality dimensions and were thus rated "unclear" for all criteria. The remaining 5 studies were observational, before-and-after studies with many inherent limitations. We believe their inclusion in this review is warranted, given the current paucity of evidence on the role of CHWs in the management and prevention of diabetes in LMICs, where the resources to conduct rigorous, high-quality effectiveness studies are often lacking. Further discussion of the quality of included studies is presented in the discussion section. Here, we present a detailed discussion of the characteristics of included studies.

Prevention of the Development of T2DM. Oba et al[54] (Thailand) used a one-group, pretest–post-test design to evaluate the effectiveness of a community participation program for T2DM prevention in a primary care unit. Overall, 160 people who had one of the following T2DM risk factors were identified: age >35 years with body mass index (BMI) > 23 kg/m^2, waist circumference >80 cm for women and >90 cm for men, and fasting blood sugar 100-125 mg/dL. Twenty health volunteers were recruited from 6 villages based on their interest in developing a T2DM program. The health volunteers provided nutritional education and established appropriate daily exercise activities for 3 months. Results showed that the mean score for health promotion behavior in relation to exercise activity was significantly higher after intervention (+0.28; P = .004), while mean scores for BMI, waist circumference, and systolic BP were significantly lower (–0.45; P = .01, –1.68; P = .04, and –2.61; P = .008, respectively). However, the mean score for health promotion behavior in relation to nutrition was not significantly higher than before intervention (+0.02; P = .76).

Balagopal et al[56] (India) investigated the effectiveness of a 6-month community-based diabetes prevention and management program in rural Gujarat. Following 4 weeks of training, 16 CHWs were engaged to provide lifestyle education, serve as community advocates, and collect data from 1638 rural Indians (81.9% response rate). CHW selection criteria and qualifications included at least a high school diploma, leadership qualities, bilingualism (English and Gujarati), and previous health care or community experience. Ten health education messages were provided face-to-face in individual and group sessions. Farmworkers, manual laborers, or those who were physically active (those who walked or bicycled for >30 minutes per day or who participated in recreational sports or brisk walking) were asked to continue their routines. Those engaged in sedentary to light physical activity were advised to be physically active for at least 30 minutes per day. All participants received personalized advice about their risk for developing diabetes, whereas overweight/obese individuals received weight-loss education in group sessions. The intervention significantly reduced blood glucose levels by 5.7 and 14.9 mg/dL in individuals with prediabetes and diabetes, respectively, and systolic and diastolic BP by 8 mm Hg and 4 mm Hg, respectively. Diabetes awareness improved by 50% in the high socioeconomic status (SES) group and

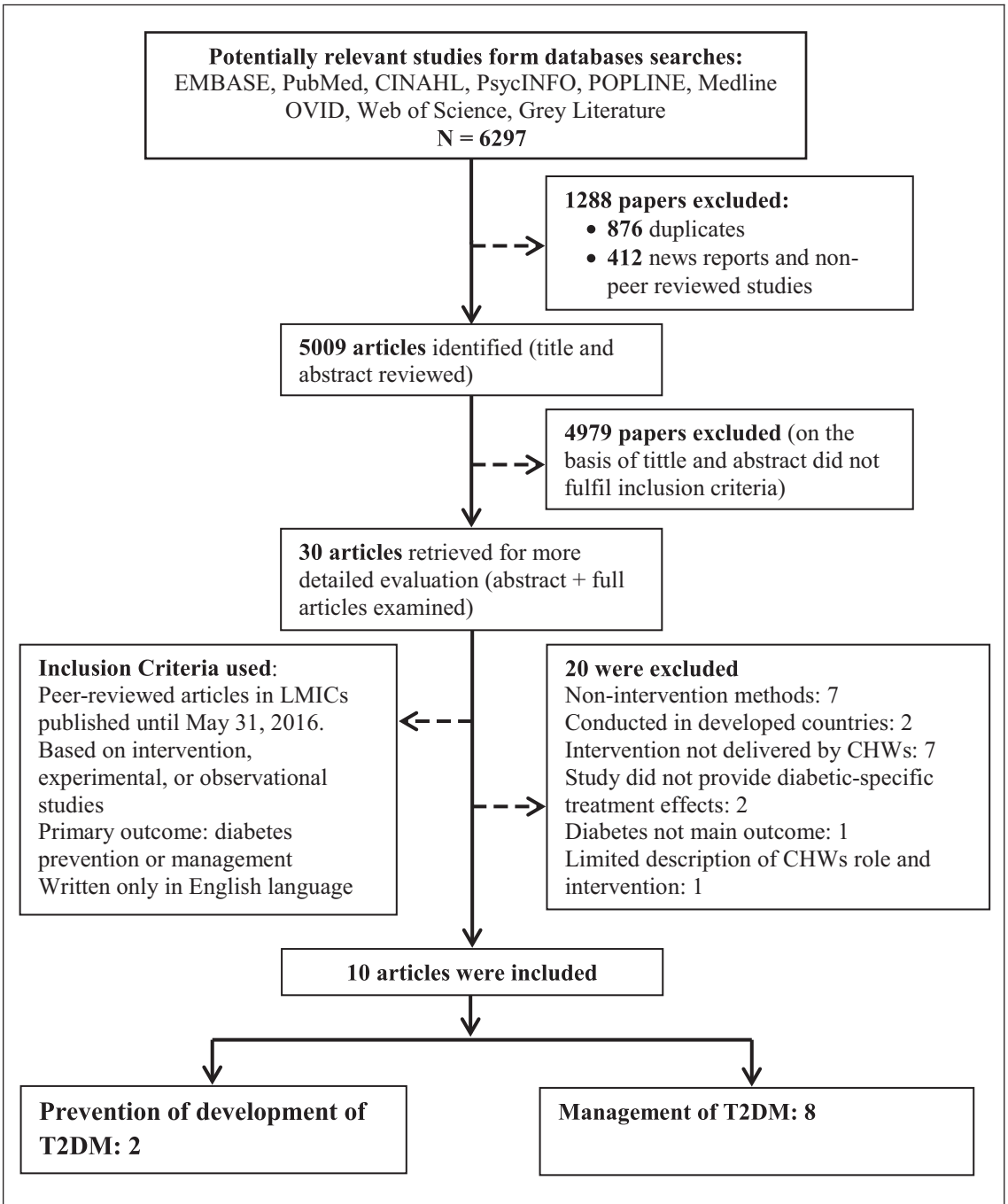

Figure 1. **Flow chart showing articles search, inclusion criteria, and selection process. Abbreviations: CHW, community health worker; LMIC, low- and middle-income country; T2DM, type 2 diabetes mellitus.**

doubled in the low SES group; general and abdominal obesity decreased by ≤1%.

Prevention of Diabetes Complications. The cross-sectional study by Farzadfar et al[55] (Iran) used data from the 2005 Iranian NCD Surveillance Survey to assess the effectiveness of the Behvarz system in managing hypertension and diabetes and to ascertain whether the effects depended on the number of community CHWs. The Behvarz system requires CHWs with at least a primary education, adequate performance on an entrance examination, and 2 years of advance training. The analytical sample consisted of

Table 2. Characteristics and Critical Appraisal of Studies for Prevention of Development of T2DM in LMICs

Author (year)	Country	Study design	Objectives	Study population	Intervention and follow-up	Outcomes measured	Key study results	Quality assessment
Oba et al (2011)[54]	Thailand	Pre- and post-test	To assess the effectiveness of T2DM prevention intervention program in a primary care unit using health volunteers	160 adults aged >35 years with BMI >23 kg/m^2, waist circumference >80 cm for women and >90 cm for men, FBS = 100-125 mg/dL	Health volunteers were recruited to provide nutritional education and set the appropriate exercise activities for every day for 3 months.	Behavior change and risk factors for T2DM	Significant higher mean score for exercise activity; significant lower mean scores of BMI; waist circumference and systolic blood pressure	Weak design. A more complete evaluation of the quality and health outcomes associated with services provided by the trained health volunteers is needed to strengthen evidence of health effects of their services.
Balagopal et al (2012)[56]	India	Pre- and post-test	To assess the effectiveness of a 6-month community-based diabetes prevention and management program using CHWs	1638 adults' residents aged >18 years	CHWs with at least a high school diploma were recruited and trained for 4 weeks to provide health education, serve as community advocates, and collect data.	Knowledge of diabetes; behavior change; fasting blood glucose level; and risk factors for T2DM	Significant increased knowledge of diabetes and consumption of fruit and vegetables and physical activity; significant reduction of BMI, blood glucose levels for individuals with prediabetes and diabetes, and blood pressure in the overall population.	Weak design. A more complete evaluation of the quality and health outcomes associated with services provided by the trained CHWs is needed to strengthen evidence of health effects of their services.

BMI, body mass index; CHW, community health worker; FBS, fasting blood sugar; LMIC, low- and middle-income country; T2DM, type 2 diabetes mellitus.

Table 3. Characteristics and Critical Appraisal of Studies for Prevention of Diabetes Complications in LMICs

Author (year)	Country	Study design	Objectives	Study population	Intervention and follow-up	Outcomes measured	Key study results	Quality assessment
Farzadfar et al[55] (2012)	Iran	Cross-sectional	To examine the effectiveness of diabetes and hypertension management by rural CHWs and to assess whether the effects depend on the number of CHWs in the community	65,619 individuals aged >24 years	Trained CHWs with at least primary education held healthy diet and lifestyle sessions, identified high-risk individuals, and referred them to physicians. After diagnosis, they conducted monthly follow-up visits.	FPG and SBP	Reduction of FPG and SBP ($P > .05$); an extra Behvarz worker per 1000 adults was related to a 0.09 mmol/L decrease in FPG among respondents.	CHW supervision and characteristics not reported; the analysis did not separate impact of interventions delivered by physicians from those delivered by trained CHWs; no mention of components of CHW intervention that are effective; cross-sectional studies measure exposure and health outcomes simultaneously, making it difficult to determine the direction of the observed associations; no measure of the relationship between degree of exposure to CHW interventions and health outcomes.
Less et al[59] (2010)	Jamaica	Prospective cohort	To examine the effectiveness of LDFs in increasing the knowledge and control of diabetes	318 adults aged 25-75 years with T2DM (159 cases and 159 controls)	Twenty-four trained LDFs provided group sessions (3 monthly visits at health centers), and 3 one-on-one LDFs home visits. Education focused on physical activities, blood glucose monitoring, hypoglycemia, and timing of meals in relation to prescription of diabetes medication.	HbA1c and BMI	Intervention group showed a mean decrease of 0.6% while the control group showed an increase of 0.6% ($P < .05$). There was no statistically significant change in BMI between groups.	CHW supervision and characteristics not reported; no mention of components of CHW intervention that are effective; the analysis did not separate impact of interventions delivered by physicians from those delivered by trained CHWs; although the study demonstrates the effectiveness of CHW-led intervention on HbA1c, evidence of quality of services or outcomes such as knowledge and behaviors was not provided; findings were based on self-reports with high potential for social desirability.
Mash et al[63] (2015)	South Africa	Cluster randomized control trial	To assess the cost-effectiveness of a group-diabetes education program delivered by health promoters	1570 T2DM patients: 710/391 in intervention group and 860/475 in control group before and after intervention, respectively.	Thirty-four health promoters were trained to provide four 60-minute sessions focusing on the description of diabetes, lifestyle modification, knowledge of medications, and the prevention of complications. Study follow-up was 1 year.	Participants' attendance, blood pressure, HbA1c, waist circumference, cholesterol level, self-care activities, quality of life, and cost-effectiveness.	Attendance: 59.4%; significant lower SBP in intervention group compared to control group; incremental cost effectiveness ratio was $1862/QALY gained.	CHW supervision and characteristics not reported; the analysis did not separate impact of interventions delivered by physicians from those delivered by trained health promoters.

(*continued on next page*)

Table 3. Continued

Author (year)	Country	Study design	Objectives	Study population	Intervention and follow-up	Outcomes measured	Key study results	Quality assessment
Micikas et al[61] (2015)	Guatemala	Pre- and post-test	To determine whether a structured, community-led diabetes self-management intervention could improve selected health outcomes for diabetic patients.	52 patients with T2DM	Eight CHWs were trained to provide lessons on self-management, medication adherence, blood glucose monitoring, portion control, and mental health. CHWs also conducted weekly home visits and pre-consults in the clinic.	Health behavior, diabetes knowledge, HbA1c, and BMI	Significant decrease in diabetes knowledge and mean HbA1c levels but no significant differences for BMI and health behavior	Weak design. A more complete evaluation of the quality and health outcomes associated with services provided by the trained health volunteers is needed to strengthen evidence of health effects of their services.
Mistry et al[58] 2015	India	Pre- and post-test	To test a community-based model for care and control through awareness and accessibility to local clinics	219 individuals	CHWs were tasked with identifying and screening high-risk individuals with subsequent referral to the clinicians for diagnosis confirmation and establishment of treatment and follow-up strategies.	Change in glycemic, lipid, and renal values	Acceptable glycemic, lipid, and renal values in addition to hypertension control among participants	Weak design. A more complete evaluation of the quality and health outcomes associated with services provided by the trained CHWs is needed to strengthen evidence of health effects of their services.
Mohammed et al[57] (2012)	India	Cohort study	To determine the effectiveness of supervised insulin administration	80 T2DM patients unresponsive to oral hypoglycemic (40 patients in intervention and 40 in control group)	One group was taught self-administration of insulin and the importance of rotation of sites of injection. The other group was monitored by a team of Anganwadi workers.	Episodes of deranged glycemic states and morbidity	Intervention group had lesser episodes of deranged glycemic states and decreased morbidity than the control group.	CHW supervision and characteristics not reported; although the study demonstrates the effectiveness of CHW-led intervention on diabetes control, evidence of quality of services or health outcomes was not provided; findings were based on self-reports.
Ndou et al[62] (2013)	South Africa	Retrospective case study	To examine the outcomes of a pilot CHW program in improving the management of hypertension and diabetes	224 patients with T2DM (56 cases and 168 controls)	Six trained CHWs provided social support and counselling to improve patient literacy and adherence, and to encourage appropriate visits to clinic.	Diabetes control	Control of hypertension was improved by CHW home visits. However, intervention group (9.1%) reported lower prevalence of diabetes control than clinic patients (26.1%).	CHW supervision and characteristics not reported; the analysis did not separate impact of interventions delivered by physicians from those delivered by trained CHWs; although the study demonstrates the effectiveness of CHW-led intervention on diabetes control, evidence of quality of services or health outcomes was not provided.
Souza et al[60] (2011)	Brazil	Randomized control trial	To evaluate effectiveness of a CHW-led diabetes education program provided to improve metabolic control of patients with T2DM	118 adults aged 50-72 years with T2DM (62 in intervention group 56 in control group)	The CHW-led intervention was a 1-month diabetes education program, consisting of four sessions (2 hours each) of educational intervention.	Diabetes knowledge, and change in HbA1c	No significant difference in diabetes knowledge between both groups, but lower HbA1c in intervention group compared to control group	CHW supervision and characteristics not reported; limited information on patient characteristics and statistical methods used since the study was reported as an abstract; although the study demonstrates the effectiveness of CHW-led interventions on HbA1c, evidence of quality of services or behavior outcomes was not provided.

CHW, community health worker; FBS, fasting blood sugar; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; LDF, lay diabetes facilitator; LMIC, low- and middle-income country; QALY, quality-of-life year; SBP, systolic blood pressure; T2DM, type 2 diabetes mellitus.

65,619 individuals (aged 25 years or older), who received follow-up for a year. CHWs held healthy diet and lifestyle sessions with the at-risk individuals and referred those at high risk to physicians. After diagnosis, CHWs conducted monthly follow-up visits. Over one-third of individuals (39.2%) with diabetes diagnoses received medication, which was associated with a 1.34 and 0.21 mmol/L decrease in fasting plasma glucose in rural and urban areas, respectively. Finally, each additional worker per 1000 adults was associated with a 0.09 mmol/L lower fasting plasma glucose.

The prospective cohort study by Less et al[59] (Jamaica) assessed the effectiveness of lay diabetes facilitators (LDFs) in increasing knowledge and improving glucose control among people living with T2DM. Twenty-four LDFs were recruited after receiving 6 hours of training on diabetes management, meal planning, hypoglycemia prevention, foot care practices, home glucose self-monitoring, and diabetes self-management. The study sample consisted of 318 diabetic patients aged 25-75 years who were recruited from 16 health centers: 159 patients were assigned to the LDF-delivered intervention and 159 from other health centers served as controls. The 6-month intervention consisted of group sessions when patients came for regular 3-month visits and 3 one-on-one LDF home visits. Education sessions focused on physical activity, blood glucose monitoring, hypoglycemia, and timing meals in relation to diabetes medication. LDFs used 3 patient self-monitoring forms: a personal eating tracker, physical activity log, and blood-glucose self-monitoring log. After 6 months, the intervention group showed a mean glycated hemoglobin (HbA1c) decrease of 0.6%, while the comparison group showed an increase of 0.6%, significant after controlling for potential confounders ($P < .05$). However, no statistically significant change in BMI occurred between groups.

Mash et al[63] (South Africa) used a pragmatic cluster randomized controlled trial design in Cape Town to explore the impact of a group diabetes education program delivered by health promoters and to evaluate the program's cost-effectiveness. Thirty-four health promoters with secondary school educations were recruited and trained to present four 60-minute sessions on diabetes characteristics, lifestyle modifications, medication awareness, and complication prevention. The study population consisted of 1570 T2DM patients attending community health centers, 710 in the intervention group and 860 in the control group. The intervention group received 4 group diabetes-education sessions, and the control group received the usual care, which consisted of ad hoc advice during consultations. Baseline data were collected prior to the intervention and 1 year later. Follow-up data was obtained from 391 patients in the intervention group and 475 in the control group. They reported no significant difference between intervention and control groups in mean HbA1c levels. Program cost per patient was $22 a year, and an incremental cost-effectiveness ratio (ICER) of $1862/QALY was projected if the intervention was repeated annually and benefits persisted.

Micikas et al[61] (Guatemala) used a pre- and post-intervention to assess whether a structured CHW intervention for diabetes self-management could improve selected health outcomes among the Tz'utujil Maya of Guatemala. The intervention, which was delivered by 8 people trained as paid diabetes health promoters, was a weekly meeting with lessons on self-management, medication adherence, blood glucose monitoring, diet portion control, and mental health. After 4 months, mean HgA1c for the sample decreased from 10.1% to 8.9%, a statistically significant decrease of 1.2% ($P = .001$). There was no marked change in mean BMI.

The pre- and post-study by Mistry et al[58] (India) evaluated a community-based model with 6 CHWs, which was developed over a 3-year period in rural Maharashtra. CHWs were tasked to identify and screen high-risk individuals and refer them to the 2 study clinicians for diagnosis confirmation, treatment, and follow-up. Post–follow-up results of 219 diabetic patients showed acceptable glycemic, lipid, and renal values in 63%, 90%, and 86% of patients, respectively.

The observational study by Mohammed et al[57] (India) was conducted in rural India to assess the effectiveness of supervised self-administered insulin among those with type 2 diabetes who were not responding to oral hypoglycemics. The intervention was delivered by a team of Anganwadi workers, rural multipurpose health workers who were given basic education about diabetes care and management, and who conducted home visits to monitor patient health status. Eighty patients with T2DM were selected from one village and divided into two groups of 40. One group was taught self-administration of insulin; the other was group-supervised by Anganwadi workers. The study reported lower episodes of deranged glycemic states and decreased morbidity compared with the control group.

The retrospective case-control study by Ndou et al[62] (South Africa) examined outcomes of a pilot CHW program to improve management of

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hypertension and diabetes in Gauteng province, South Africa. Six CHWs underwent 14 weeks of training to provide social support and counselling for improving patient literacy and medication adherence, and to encourage appropriate visits to primary health care clinics. The analytic sample consisted of 56 intervention patients and 168 controls. Intervention patients were visited once a month by a CHW, whereas control patients attended the clinic once a month. Patients were required to visit the clinic every 6 months for a physical examination by a doctor, who also provided prescription renewal. Participant ages ranged from 51 to 92 years. Despite the greater age and comorbidity of the intervention group, findings suggest that hypertension control improved with CHW home visits in comparison to usual care.

The randomized controlled trial by Souza et al[60] (Brazil) assessed the effectiveness of a diabetes education program delivered by CHWs in a primary care unit. Eight CHWs worked with 118 patients who were randomized into 2 groups to participate in either a 1-month (4 sessions of 2 hours each) diabetes education program (intervention group, n = 62) or an education course on other health issues (control group, n = 56). Mean age was 61 (SD 11) years, and no significant differences were evident between groups at baseline. After a 4-month follow-up period, no change was observed in T2DM knowledge scores (intervention: 15 [SD 5.2] versus 15 [SD 6.0] and control group: 14 [SD 4.7] versus 15 [SD 5.5], $P = .43$). HbA1c levels were reduced in both groups (intervention 9.1% [SD 2.2%] versus 7.5% and control 9.2% [SD 2.1] versus 7.9% [SD 2.1%], $P < .001$), but no statistically significant differences between groups were observed ($P = .22$).

DISCUSSION

This review presents evidence for the effectiveness of T2DM prevention and management interventions led by CHWs. Positive outcomes were reported in 7 of 10 studies. These included increased awareness of symptoms and prevention measures; adopted treatment-seeking and prevention practices; improved medication adherence; and improved fasting blood sugar, HbA1c, and BMI levels. Three studies[55,61,62] showed no significant differences.

Study quality assessment revealed variable quality. Across the 10 included studies, there was significant heterogeneity in sample characteristics such as size, age, inclusion criteria, type, and follow-up length. Sample sizes ranged from 16 to 65,619, ages from 25 to 92 years, and follow-up length from 3 months to 3 years. In addition, information on CHW selection criteria and characteristics was limited. None of the studies reported the age and sex of CHWs, and information on CHW educational backgrounds and relevant experience was incomplete. There was significant heterogeneity in CHW sample size—from 1 for 2 patients[61] to 1 for 102 patients.[56] Training of CHWs also varied in content and intensity, and the roles and responsibilities of CHWs varied widely and could be classified into three types: patient education,[54-56,59-63] identification and referral,[55,58,61] and social support.[55-57,59-61] Therefore, it was difficult to determine whether type of training influenced effectiveness of CHW interventions. A small number of studies did not permit sub-group analysis to determine which CHW intervention type was most effective. As noted by Norris et al,[26] their review of the effects of CHW interventions in high-income countries and the wide variability in reported roles and duties of CHWs makes it difficult to evaluate CHW effectiveness or to draw conclusions about their optimal roles in community interventions.

Four studies used the pre- and post-test design to assess the effectiveness of CHW-led interventions.[54,56,58,61] Although this design is useful in addressing potential ethical concerns associated with randomized controlled trials or prospective cohort designs,[64] the lack of a comparison group limits the degree to which observed health outcomes can be attributed to CHWs. Equally, 3 studies[56-58] assessed outcome measures based on self-reports, which are known to be subject to the influence of social desirability.[64] More importantly, no study assessed the relationship between health outcomes and exposure to CHW-provided interventions. Only one study reported cost-effectiveness outcomes and quality of life,[63] patient[63] and CHW[62] experiences, and morbidity.[57]

Limitations. Because few studies were identified for this review, robust conclusions on effectiveness could not be drawn. In addition, most studies were conducted in Asia, limiting generalizability. Our assessment of each intervention study was limited to published data, and attempts made to contact authors for additional information were not always successful. Therefore, in some cases, the reporting of study details was inadequate, particularly for descriptions of CHW education, training, experience, and supervision. Several studies highlighted the potential for publication bias in LMICs, as many interventions involving CHWs were not implemented with an evaluation component.[65] It is likely that many community programs, local health departments, or private health care organizations that include CHWs in their

teams have conducted evaluations, but these data were not published.[66]

Implications for Research and Practice. With the growing need to reduce the escalating burden of diabetes in LMICs,[9] further research is needed into the influences of CHWs on disease awareness, health behavior, and health outcomes. Where CHW interventions showed benefits, further research is needed to understand which components make the interventions effective. Therefore, clear descriptions of training and supervision procedures and specified functions and types of CHWs are needed.[67,68]

Further research is also needed to determine both facilitators of and barriers to successful implementation of CHW interventions. Participant expectations and satisfaction are key issues,[69] and only one study examined participant experience. It is also important to examine health workers' perceptions of CHWs[70] and health care system barriers to strategies for integrating CHWs into health care teams. Additionally, examination of CHW satisfaction and perceptions of barriers is necessary.[71] Future research needs to incorporate measures for determining quality of life, health care use, and cost-effectiveness. Additional cost-effectiveness studies can help determine whether CHW interventions are a cost-effective alternative to other diabetes-related health interventions.

Finally, this review highlights the need for more CHW interventions in preventing the development of T2DM, as only 2 such studies were identified. Also, as already advocated by Rawal et al[15] and Afable et al,[72] more evidence is needed on the efficacy, cost-effectiveness, and sustainability of culturally appropriate lifestyle interventions in LMICs. It is important to monitor CHW diabetes prevention efforts in LMICs, as approximately 10% of individuals with prediabetes progress to T2DM annually.[16] Improved T2DM awareness among populations where traditional health care interventions have often failed represents an important step in raising diabetes health literacy among target populations. These improvements, however, must be demonstrated to lead to positive changes in lifestyle, self-care behaviors, physiological outcomes, and improved quality of life.

REFERENCES

1. World Health Organization. Noncommunicable Diseases Country Profiles 2014. Geneva: World Health Organization; 2014 Available at: http://www.who.int/nmh/publications/ncd-profiles-2014/en/. Accessed June 9, 2017.
2. United Nations. Transforming our World: The 2030 Agenda for Sustainable Development. 2015 Available at: https://sustainabledevelopment.un.org/post2015/transformingourworld. Accessed June 9, 2017.
3. World Health Organization. Noncommunicable Diseases Progress Monitor 2015. Geneva: WHO; 2015.
4. World Health Organization. Global Report on Diabetes. Geneva: World Health Organization. 2016 Available at: http://www.who.int/diabetes/global-report/en/. Accessed June 9, 2017.
5. International Diabetes Federation. IDF Diabetes Atlas 2015. 7th ed. Brussels: International Diabetes Federation; 2015.
6. World Health Organization. Sixty-First World Health Assembly. Geneva: World Health Organization; 2008.
7. World Health Organization. The Diabetes Declaration and Strategy for Africa; A Call to Action and Plan of Action to Prevent and Control Diabetes and Related Chronic Diseases. Geneva: World Health Organization-AFRO Region; 2006.
8. Zhang P, Zhang X, Brown J, et al. Global healthcare expenditure on diabetes for 2010 and 2030. Diabetes Res Clin Pract 2010;87:293–301.
9. Dagogo-Jack S. Primary prevention of type 2 diabetes: an imperative for developing countries. Diabetes Mellitus. In: Developing Countries and Underserved Communities. New York: Springer International Publishing; 2017:7–31.
10. Barceló A, Aedo C, Rajpathak S, et al. The cost of diabetes in Latin America and the Caribbean. Bull World Health Organ 2003;81:19–27.
11. Chatterjee S, Davies M. Type 2 diabetes: recent advances in diagnosis and management. Prescriber 2015;26:15–21.
12. Kibirige D, Atuhe D, Sebunya R, et al. Suboptimal glycaemic and blood pressure control and screening for diabetic complications in adult ambulatory diabetic patients in Uganda: a retrospective study from a developing country. J Diabetes Metab Disord 2014;13:40.
13. Musenge EM, Manankov A, Mudenda B, et al. Glycaemic control in diabetic patients in Zambia. Pan Afr Med J 2014;19:354.
14. Samb B, Desai N, Nishtar S, et al. Prevention and management of chronic disease: a litmus test for health-systems strengthening in low-income and middle-income countries. Lancet 2010;376:1785–97.
15. Rawal LB, Tapp RJ, Williams ED, et al. Prevention of type 2 diabetes and its complications in developing countries: a review. Int J Behav Med 2012;9:121–33.
16. Tabák A, Herder C, Rathmann W, Brunner E, Kivimäki M. Prediabetes: a high-risk state for diabetes development. Lancet 2012;379:2279–90.
17. Gill GV, Price C, Shandu D, et al. An effective system of nurse-led diabetes care in rural Africa. Diabet Med 2008;25:606–11.
18. Mamo Y, Seid E, Adams S, et al. A primary healthcare approach to the management of chronic disease in Ethiopia: an example for other countries. Clin Med 2007;7:228–31.
19. Temu F, Leonhardt M, Carter J, et al. Integration of non-communicable diseases in healthcare: tackling the double

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May–August 2017: 661–675

burden of disease in African settings. Pan Afr Med J 2014;18:202.
20. Haines A, Sanders D, Lehmann U, et al. Achieving child survival goals: potential contribution of community health workers. Lancet 2007;369:2121–31.
21. Bhutta ZA, Lassi ZS, Pariyo G, Huicho L. Global Experience of Community Health Workers for Delivery of Health-Related Millennium Development Goals: A Systematic Review, Country Case Studies, and Recommendations for Integration Into National Health Systems. Global Health Workforce Alliance; 2010:249–61.
22. Kok MC, Dieleman M, Taegtmeyer M, et al. Which intervention design factors influence performance of community health workers in low- and middle-income countries? A systematic review. Health Policy Plan 2014;30:1207–27.
23. Perry HB, Zulliger R, Rogers MM. Community health workers in low-, middle-, and high-income countries: an overview of their history, recent evolution, and current effectiveness. Annu Rev Public Health 2014;35:399–421.
24. Satterfield DW, Burd C, Valdez L, et al. The "'in-between'" people: participation of community health representatives in diabetes prevention and care in American Indian and Alaskan Native communities. Health Promot Pract 2002;3:166–75.
25. Michael YL, Farquhar SA, Wiggins N, et al. Findings from a community-based participatory prevention research intervention designed to increase social capital in Latino and African American communities. J Immigr Minor Health 2008;10:281–9.
26. Norris SL, Chowdhury FM, Van Le K, et al. Effectiveness of community health workers in the care of persons with diabetes. Diabet Med 2006;23:544–56.
27. Lewin S, Munabi-Babigumira S, Glenton C, et al. Lay health workers in primary and community healthcare for maternal and child health and the management of infectious diseases. Cochrane Database Syst Rev 2010;(3):CD004015.
28. Van Ginneken N, Tharyan P, Lewin S, et al. Non-specialist health worker interventions for the care of mental, neurological and substance-abuse disorders in low-and middle-income countries. Cochrane Database Syst Rev 2013;(11):CD009149.
29. Tsolekile LP, Puoane T, Schneider H, et al. The roles of community health workers in management of non-communicable diseases in an urban township. Afr J Prim Health Care Fam Med 2014;6:1–8.
30. Koenig SP, Léandre F, Farmer PE. Scaling-Up HIV treatment programs in resource-limited settings. AIDS 2014;18(Suppl 3):S21–5.
31. Khetan AK, Purushothaman R, Chami T, et al. The effectiveness of community health workers in CVD prevention in LMIC. Glob Heart 2016;pii:S2211-8160;30701–3.
32. Cummings DM, Lutes LD, Littlewood K, et al. A randomized trial using community health workers to deliver a lifestyle intervention program in African American women with type 2 diabetes: design, rationale, and baseline characteristics. Contemp Clin Trials 2013;36:147–53.
33. Kane EP, Collinsworth AW, Schmidt KL, et al. Improving diabetes care and outcomes with community health workers. Fam Pract 2016;33:523–8.
34. Palmas W, March D, Darakjy S, et al. Community health worker interventions to improve glycemic control in people with diabetes: a systematic review and meta-analysis. J Gen Intern Med 2015;30:1004–12.
35. Perez-Escamilla R, Damio G, Chhabra J, et al. Impact of a community health workers–led structured program on blood glucose control among Latinos with type 2 diabetes: the DIALBEST Trial. Diabetes Care 2014;38:197–205.
36. Ryabov I. Cost-effectiveness of community health workers in controlling diabetes epidemic on the U.S.–Mexico border. Public Health 2014;128:636–42.
37. Jeet G, Thakur JS, Prinja S, et al. Community health workers for non-communicable diseases prevention and control in developing countries: evidence and implications. PLoS ONE 2017;12:e0180640.
38. DePue JD, Rosen RK, Seiden A, et al. Implementation of a culturally tailored diabetes intervention with community health workers in American Samoa. Diabetes Educ 2013;39:761–71.
39. Zhong X, Wang Z, Fisher EB, et al. Peer support for diabetes management in primary care and community settings in Anhui Province, China. Ann Fam Med 2015;13:S50–8.
40. Jafar TH, Jehan I, Liang F, et al. Control of blood pressure and risk attenuation: post trial follow-up of randomized groups. PLoS ONE 2015;10:e0140550.
41. Thankappan KR, Mini GK, Hariharan M, et al. Smoking cessation among diabetic patients in Kerala, India: 1-year follow-up results from a pilot randomized controlled trial. Diabetes Care 2014;37:e256–7.
42. Wattana C, Srisuphan W, Pothiban L, et al. Effects of a diabetes self-management program on glycemic control, coronary heart disease risk, and quality of life among Thai patients with type 2 diabetes. Nurs Health Sci 2007;9:135–41.
43. Goldhaber-Fiebert JD, Goldhaber-Fiebert SN, Tristan ML, et al. Randomized controlled community-based nutrition and exercise intervention improves glycemia and cardiovascular risk factors in type 2 diabetic patients in rural Costa Rica. Diabetes Care 2003;26:24–9.
44. Love MB, Gardner K, Legion V. Community health workers: who they are and what they do. Health Educ Behav 1997;24:510–22.
45. Centers for Disease Control and Prevention. Addressing Chronic Disease through Community Health Workers: A Policy Crief on Community Health Workers. Second ed. Atlanta, Georgia: Centers for Disease Control and Prevention; 2015.
46. World Bank. World Bank Country and Lending Groups. Washington DC, USA. 2016 Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed February 22, 2017.
47. Institute for Work and Health. Primary, secondary and tertiary prevention. Ottawa, Canada. 2015 Available at: https://www.iwh.on.ca/wrmb/primary-secondary-and-tertiary-prevention. Accessed June 21, 2017.
48. Gilmore B, McAuliffe E. Effectiveness of community health workers delivering preventive interventions for maternal and child health in low- and middle-income countries: a systematic review. BMC Public Health 2013;13:847.
49. Li Y, Marshall CM, Rees HC, et al. Intimate partner violence and HIV infection among women: a systematic review and meta-analysis. J Int AIDS Soc 2014;17:188845.
50. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2009 Available at: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed May 10, 2017.
51. National Collaborating Centre for Environmental Health (NCCEH). A Primer for Evaluating the Quality of Studies on Environmental Health Critical Appraisal of Cross-Sectional Studies. Vancouver, BC, Canada. 2016 Available at: http://www.ncceh.ca/sites/default/files/Critical_Appraisal_Cross-Sectional_Studies_Aug_2011.pdf. Accessed May 15, 2017.
52. National Institutes of Health. Quality assessment tool for before-after studies with no control group. Bethesda, MD, USA. 2014 Available at: https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-redu

ction/tools/before-after. Accessed August 29, 2017.
53. Schulz KF, Chalmers I, Hayes RJ, et al. Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. JAMA 1995;273:408–12.
54. Oba N, McCaffrey R, Choonhapran P, et al. Development of a community participation program for diabetes mellitus prevention in a primary care unit, Thailand. Nurs Health Sci 2011;13:352–9.
55. Farzadfar F, Murray CJL, Gakidou E, et al. Effectiveness of diabetes and hypertension management by rural primary health-care workers (Behvarz workers) in Iran: a nationally representative observational study. Lancet 2012;379:47–54.
56. Balagopal P, Kamalamma N, Patel TG, et al. A community-based participatory diabetes prevention and management intervention in rural India using community health workers. Diabetes Educ 2012;38:822–34.
57. Mohammed R, Mohammed HS, Banu A, et al. Self-administered insulin versus supervised insulin administration: an observational study. ADA 2012;61:A622–3.
58. Mistry NF, Mote B, Garda L, et al. A community based model for care and control of type 2 diabetes in rural Western India. Trop Med Int Health 2015;20:61.
59. Less LA, Ragoobirsingh D, Morrison EY, et al. A preliminary report on an assessment of a community-based intervention for diabetes control in adults with type 2 diabetes. J Fam Pract 2010;27:i46–52.
60. Souza CF, Dalzochio MB, Zucatti AT, et al. Community health workers effectiveness in diabetes education. Diabetologia 2011;54:S380.
61. Micikas M, Foster J, Weis A, et al. A community health worker intervention for diabetes self-management among the Tz'utujil Maya of Guatemala. Health Promot Pract 2015;16:601–8.
62. Ndou T, Van Zyl G, Hlahane S, et al. A rapid assessment of a community health worker pilot programme to improve the management of hypertension and diabetes in Emfuleni subdistrict of Gauteng Province, South Africa. Glob Health Action 2013;6:19228.
63. Mash R, Kroukamp R, Gaziano T, et al. Cost-effectiveness of a diabetes group education program delivered by health promoters with a guiding style in underserved communities in Cape Town, South Africa. Patient Educ Couns 2015;98:622–6.
64. Marsden E, Torgerson CJ. Single group, pre-and post-test research designs: some methodological concerns. Oxf Rev Educ 2012;38:583–616.
65. Reynolds J, DiLiberto D, Mangham-Jefferies L, et al. The practice of "doing" evaluation: lessons learned from nine complex intervention trials in action. Implement Sci 2014;9:75.
66. Lehmann U, Sanders D. Community Health Workers: What Do We Know About Them? The State of the Evidence on Programmes, Activities Costs and Impacts on Health Outcomes of Using Community Health Workers. Geneva: WHO; 2007.
67. Cherrington A, Ayala GX, Amick H, et al. Applying the community health worker model to diabetes management: using mixed methods to assess implementation and effectiveness. J Health Care Poor Underserved 2008;19:1044–59.
68. Shah M, Kaselitz E, Heisler M. The role of community health workers in diabetes: update on current literature. Curr Diab Rep 2013;13:163–71.
69. Sando D, Geldsetzer P, Magesa L, et al. Evaluation of a community health worker intervention and the World Health Organization's Option B versus Option A to improve antenatal care and PMTCT outcomes in Dar es Salaam, Tanzania: study protocol for a cluster-randomized controlled health systems implementation trial. Trials 2014;15:359.
70. Sidat M, Ormel H, Ndima S, et al. Exploring competing experiences and expectations of the revitalized community health worker programme in Mozambique: an equity analysis. Hum Resour Health 2015;13:54.
71. Sanou AK, Jegede AS, Nsungwa-Sabiiti J, et al. Motivation of community health workers in diagnosing, treating, and referring sick young children in a multicountry study. Clin Infect Dis 2016;63:S270.
72. Afable A, Karingula NS. Evidence based review of type 2 diabetes prevention and management in low and middle income countries. World J Diabetes 2016;7:209–29.