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Review

Rural diabetes prevalence quintuples over twenty-five years in low- and middle-income countries: A systematic review and meta-analysis

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ABSTRACT

Aims: To verify the assertions that diabetes pandemic may be spreading across rural parts of low- and middle-income countries (LMICs), we performed a systematic review of published studies reporting diabetes prevalence in rural parts of LMICs.

Methods: Electronic databases (EMBASE and MEDLINE) were searched for papers published from 1990 to 2011. Two independent reviewers screened the articles using structured criteria for inclusion and performed full-text reviews. Pooled prevalence of diabetes was estimated using meta-analysis. Potential factors influencing the estimates were identified by meta-regression and used for sensitivity analyses.

Results: Rural prevalence of diabetes of LMICs was 5.6% (95% CI = 4.6–6.6), and similar between men and women. This estimate remained robust in separate sensitivity analyses accounting for study quality, level of heterogeneity, age, and sex. In a multivariate meta-regression analysis, pooled prevalence varied by study year and region. Diabetes prevalence increased over time, from 1.8% (1.0–2.6) in 1985–1989, 5.0% (3.8–6.3) in 1990–1994, 5.2% (4.1–6.2) in 1995–1999, 6.4% (5.1–7.7) in 2000–2004, and to 8.6% (6.4–10.7) for 2005–2010 ($p = 0.001$ for secular trend).

Conclusions: Prevalence of diabetes in rural parts of LMICs has risen dramatically. As 55% of LMIC populations live in rural areas, this trend has enormous implications for the global burden of diabetes.

Contents

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1. Introduction

Diabetes is a 21st century pandemic with huge morbidity, mortality, and economic burdens. The most recent global estimates posit that there were 285 million people living with diabetes worldwide in 2010 and that this number is projected to reach 438 million by 2030 [1]. The growth of diabetes in low- and middle-income countries (LMIC), largely driven by dramatic increases in type 2 diabetes, is intricately related to lifestyle changes associated with globalization and modernization of lifestyles. In 2004, an estimated 3.4 million people died from consequences of high blood glucose [2]. Moreover, the World Health Organization (WHO) projects that diabetes deaths will double between 2005 and 2030 with more than 80% of diabetes deaths occurring in LMICs [2].

Though the increases in diabetes burdens in urban parts of LMICs are well recognized, recent studies suggest that high prevalence of diabetes may not be limited to urban areas. The prevalence of diabetes in rural China, for example, was noteworthy, even comparable to the prevalence observed in the urban population (8.2% and 11.2%, respectively) [3]. Likewise, the prevalence of diabetes observed in rural populations of India, Pakistan, and Bangladesh were also high [4–6]. It is not clear, however, whether the prevalence of diabetes in rural parts of LMICs is high across all regions of the world or how much prevalence has changed over time. As 55% of LMIC populations worldwide live in rural areas [7], recognition of the current magnitude and trends of these burdens will be crucial in prioritization and resource allocation for health.

Therefore, to estimate the prevalence of diabetes, which is largely driven by type 2, across all LMIC rural areas, we performed a systematic review of studies published between 1990 and 2011, and present synthesized findings following PRISMA guidelines [8].

2. Materials and methods

2.1. *Search strategy and selection criteria (Fig. 1)*

We searched the electronic peer-reviewed literature databases (EMBASE and MEDLINE) for papers that reported rural diabetes prevalence and were published between January 1, 1990 to October 1, 2010, without language restrictions. In May 2011, we undertook an updated search to identify the most recent publications on the topic. Search strategies were developed and implemented with assistance from a reference librarian with expertise in database searches. Search term combinations were ''diabetes mellitus,'' ''rural,'' and ''epidemiology or prevalence''. All references were compiled into one database and a reference manager (EndNote library Version X4, CA). Two independent reviewers screened titles and abstracts for relevant studies with population-based objective cross-sectional survey data on diabetes in LMIC rural settings, excluding studies conducted exclusively in high-income countries (as defined by the World Bank) [9]. Other exclusion criteria included the following: gestational diabetes, type 1 diabetes, uncommon forms of diabetes, conference abstracts (insufficient data to allow rigorous quality assessments and thus, inclusion in our analyses), non-original research (review, editorial, letter, or commentary articles), and all studies targeting specific ethnic or age-groups (e.g., children or elderly only) that were not considered representative of the nation as a whole. When there was more than one report relating to the same cohort, the report with the most relevant and/or updated information was included. Disagreement was settled by consensus among all authors. The Google Translate feature was utilized to translate studies in foreign languages when possible. Studies published in languages for which translations were not available were excluded.

Full-texts of the remaining studies were obtained, and additional studies were excluded based on diagnostic criteria and sampling methods. Studies not using a standard definition of diabetes mellitus (WHO criteria [10] or American Diabetes Association guidelines [11]) were excluded. Studies using non-random (e.g., convenience, purposive) sampling were also excluded.

Structured quality assessments were performed using full-texts of studies remaining after the application of exclusion criteria. Each study was critically reviewed to determine whether: (1) there was significant non-response bias, which was defined as response rate $< 75\%$ with no specified analysis comparing responders to non-responders; (2) standardized, objective data collection methods were used with data obtained directly from subjects (e.g., through blood samples); and (3) appropriate statistical methods were employed. We excluded studies that failed to meet at least two out of the three characteristics described. Of the studies included, relevant data were not available for 20 published studies. Corresponding authors were contacted via email yielding responses from five. The remaining15 studies were excluded due to insufficient data.

2.2. *Data gathering and statistical analysis*

Data were imported into STATA version 11.1 to calculate pooled estimates and 95% confidence intervals of diabetes prevalence, using a random-effects model with the DeSimonian and Laird method [12]. Galbraith plot of heterogeneity and I [2] statistic were also used to assess the heterogeneity among studies.

For 64 out of 76 (84%) studies providing the year during which the study was conducted, prevalence estimates over increasing five-year periods (1985–1989, 1990–1994, 1995–1999, 2000–2004, to 2005–2010) were calculated. The starting year of each study was the preferred categorization. Additionally, prevalence estimates over increasing five-year periods by publication year (1990–1995, 1996–2000, 2001–2005, to 2006–2011) were also calculated. The secular trend across time periods was statistically evaluated.

Studies were grouped into six geographic regions: East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, South Asia, and Sub-Saharan Africa, using the World Bank region definitions [9]. Pooled estimates of diabetes prevalence over the 25-year period were calculated for each geographic region of the world.

To explore the sources of heterogeneity among studies, a meta-regression analysis was performed using study-quality covariates (i.e., non-response biases, standard data collection methods, and statistical methods used in each of the studies). Adding data collection method as a covariate to the analysis was not necessary as all included studies used standard, objective data collection methods (i.e., blood sample collection and glucose estimation). Additionally, the influence of the 1997 change in diagnostic criteria was evaluated in the meta-regression analysis. Studies were subcategorized into two groups: studies that based diabetes diagnosis on the older fasting plasma glucose (FPG) level threshold of 7.8 mmol/l [13] and studies that used the current diagnostic FPG level threshold of 7.0 mmol/l and/or 2-h post-challenge glucose level of 11.1 mmol/l [10,11].

Due to significant heterogeneity noted among the studies, we conducted additional sensitivity analyses based on potentially influential variables, namely study quality, study heterogeneity level, diabetes diagnostic criteria, sex, and age.

3. Results

Fig. 1 shows the study selection process. In total, the searches yielded a total of 1966 publications (1857 from the original

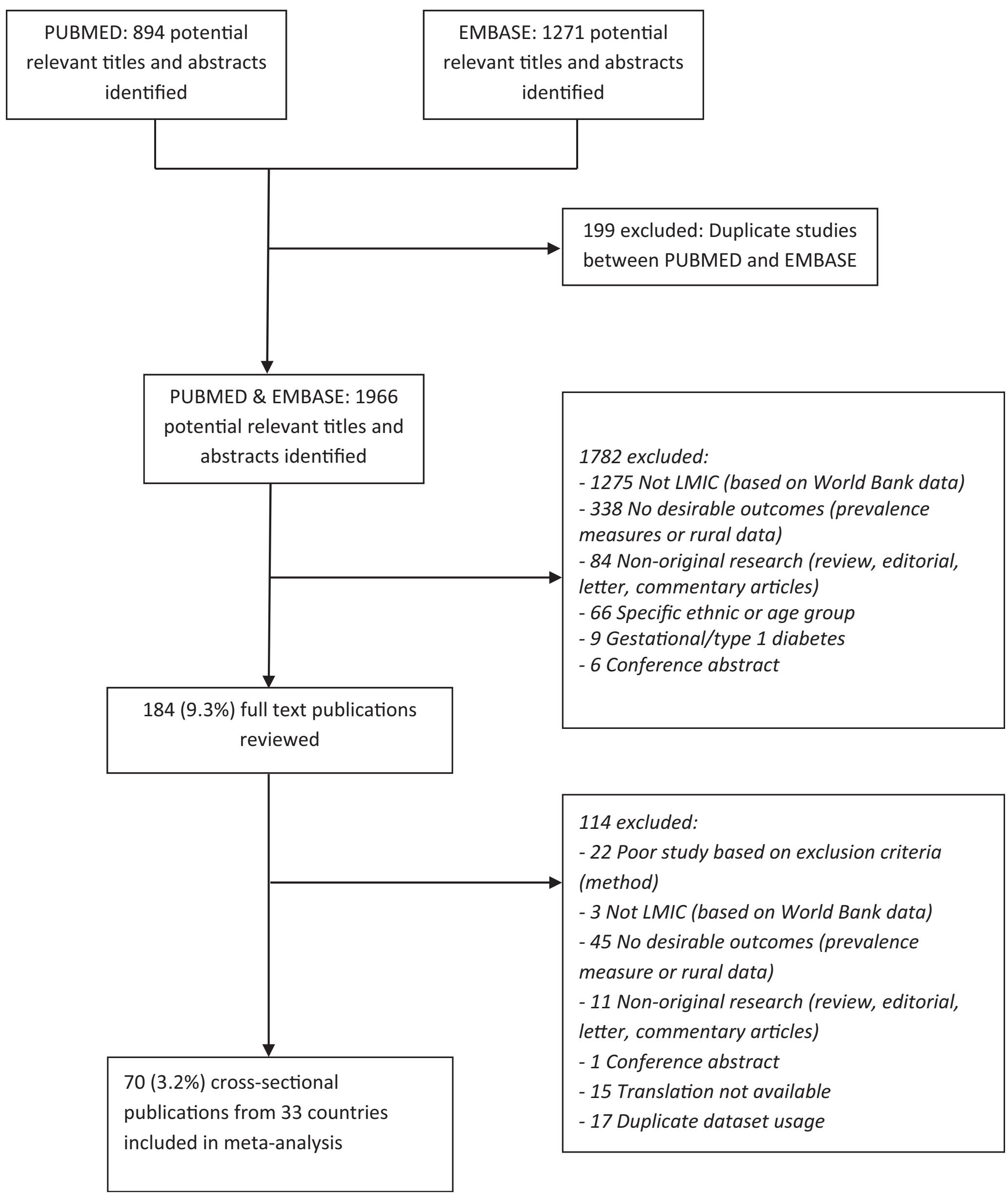

Fig. 1 – Flow diagram for selection of studies.

Table 1 – Characteristics of included studies.

Author, year	Country	Study period	Study	Setting	Design	Sample frame	Sample method	Age range	Mean age	Male (%)	DM type	Diagnostic method[b]	Quality criteria met[a]	Description of rural area used
Abdul-Rahim, 2001 [33]	Palestine	1996	Sub-national, community	Household	Cross-sectional	Census	Population	30–65	43.8	42	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Population < 4000
Aekplakorn, 2007[26]	Thailand	2004	National	Household	Cross-sectional	Government register	Multi-stage, stratified	≥15	NA	50	1,2	FPG ≥ 7.0 mmol/l	1,2,3,4	Unspecified
Ali, 1993 [23]	Malaysia	1992	Sub-national, community	Clinic	Cross-sectional	Unspecified	Population	≥18	35.6	NA	2	OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Aspray, 2000 [34]	Tanzania	1996–7	Sub-national, community	Household	Cross-sectional	Demographic surveillance system	Simple	≥15	NA	43.2	1,2	FWBG ≥ 6.1 mmol/l	2,3,4	Farming community, Population < 4000
Baechler, 2002 [35]	Chile	1999–2000	Sub-national, provincial	Clinic	Cross-sectional	Unspecified	Multi-stage, cluster	≥20	NA	NA	1,2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Balagopal, 2008 [36]	India	2002–3	Sub-national, community	Household	Cross-sectional	Census	Population	≥18	40.3	48.3	2	FPG ≥ 7.0 mmol/l	3,4	950 residents (>10 years of age)
Balde, 2007 [37]	Guinea	2003	Sub-national, community	Household	Cross-sectional	Census	Simple	≥35	45.6	55.1	1,2	FWBG ≥ 6.1 mmol/l	3,4	Definition based on isolation, difficulty of access by road, low levels of infrastructure, traditional lifestyle and diet
Baltazar, 2004 [38]	Philippines	2002	Sub-national, community	Household	Cross-sectional	Unspecified	Cluster	≥20	NA	32.7	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Baranguays in the outskirts of municipalities
Bouguerra, 2007 [39]	Tunisia	1996–7	National	Household	Cross-sectional	Census	Simple	≥20	NA	NA	1,2	FPG ≥ 7.8 mmol/l	1,2,3	Urban area defined by National Institute of Statistics
Campos, 1992 [40]	Costa Rica	1988	Sub-national, community	Household	Cross-sectional	Unspecified	Stratified	20–65	NA	47	1,2	FPG ≥ 7.8 mmol/l	2,3,4	Unspecified
Chaisiri, 1997 [41]	Thailand	1995	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	30–74	46 (median)	42	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Villages (only those with >100 households)
Chow, 2006 [4]	India	2005	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	≥30	46.8	NA	1,2	FPG ≥ 7.0 mmol/l	2,3	Unspecified
Collins, 1994 [42]	Western Samoa - Poutasi	1991	Sub-national, community	Household	Cross-sectional	Census	Population	25–74	NA	50	2	OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Dong, 2005 [43]	China	2001–2	Sub-national, community	Household	Cross-sectional	Unspecified	Stratified Cluster	20–74	45.2	38	1,2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Based on economic development status
Dowse, 1994 [24]	Papua New Guinea- Wanigela	1991	Sub-national, community	Household	Cross-sectional	Census	Population	≥25	45.7	29.9	2	OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Elbagir, 1996 [44]	Sudan	NA	Sub-national, provincial	Household	Cross-sectional	Unspecified	Simple	≥25	NA	37	1,2	OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Elbagir, 1998 [45]	Sudan	NA	Sub-national, community	Household	Cross-sectional	Unspecified	Multi-stage, cluster	25–85	40 (median)	27	1,2	OGTT ≥ 11.1 mmol/l	3,4	Engaged mainly in subsistence farming
Evaristo-Neto, 2010 [46]	Angola	NA	Sub-national, community	Household	Cross-sectional	Residential addresses	Simple	30–69	54.3	30	1,2	FPG ≥ 7.0 mmol/l	2,3,4	60 km north of Luanda (capital of Angola); 15 villages with "rural" characteristics
Gao, 2009 [47]	China	2001–2	Sub-national, community	Household	Cross-sectional	Streets maps (households)	Stratified Cluster	≥35	50.4	39.3	2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Based on administration units

Gu, 2003 [48]	China	2000–1	National	Clinic	Cross-sectional	Unspecified	Multi-stage, stratified	35–74	50.2	51.4	1,2	FPG ≥ 7.0 mmol/l	2,3,4	Economic development status
Guerro Romero, 1997 [16]	Mexico	1993–4	Sub-national, community	Household	Cross-sectional	Census	Simple	30–82	48.6	26.2	2	FPG ≥ 7.8 mmol/l	3,4	627 communities; 90% have <250 inhabitatns
Gunaid, 2008 [49]	Yemen	2000	Sub-national, community	Clinic	Cross-Sectional	Unspecified	Multi-stage	≥35	55.9	48	2	FWBG ≥ 6.1 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Semi-rural: 20 km from Sana'a; consists of 16 small villages with 70,478 inhabitants
Herman, 1995 [50]	Egypt	1991–4	Sub-national, community	Household	Cross-sectional	Census	Simple	≥20	NA	NA	1,2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	30 miles north of Cairo
Hussain, 2007 [51]	Bangladesh	1999–2000	Sub-national, community	Household	Cross-sectional	Census	Simple	≥20	37.5	NA	2	FWBG ≥ 6.1 mmol/l	2,3,4	Livelihood primarily related to agriculture and no ''urban housing'' provided like water, gas, sanitation
Husseini, 2003 [52]	Palestine	1996	Sub-national, community	Household	Cross-sectional	Census	Population	30–65	43.8	NA	1,2	OGTT ≥ 11.1 mmol/l	3,4	15 km outside of Ramallah city
Ilangsekera, 2004 [53]	Sri Lanka	2000	Sub-national, community	Unspecified	Cross-sectional	Electoral Register	Multi-stage	19–80	NA	47	1,2	FPG ≥ 7.0 mmol/l	2,3	Population 25,605
Kadiki, 2001 [54]	Libya	1998–9	Sub-national, community	Household	Cross-sectional	Unspecified	Multi-stage, cluster	≥20	NA	36.2	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Inhabitants are farmers
Katulanda, 2008 [55]	Sri Lanka	2005–6	Sub-national, provincial	Household	Cross-sectional	Village officer units (Smallest administrative unit)	Cluster	≥18	NA	40	1,2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Khebir, 1996 [56]	Malaysia	1994	Sub-national, community	Household	Cross-sectional	Census	Simple	≥15	NA	43.1	2	OGTT ≥ 11.1 mmol/l	3,4	Unspecified
King, 1998 [57]	Uzbekistan	NA	Sub-national, community	Household	Cross-sectional	Census	Population	≥35	48.2	27.8	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	20 km from Fergana capital
King, 2002 [58]	Uzbekistan	NA	Sub-national, community	Household	Cross-sectional	Census	Population	≥35	48.7	40	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Economy is primarily agricultural
King, 2005 [59]	Cambodia	2004	Sub-national, community	Household	Cross-sectional	Census	Stratified	≥25	44.7	35.6	1,2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Traditional Khmer-Melanesian culture and lifestyle
Lin, 2009 [60]	China	2007–8	Sub-national, provincial	Household	Cross-sectional	Unspecified	Multi-stage, cluster	20–74	NA	38	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	National Bureau of Statistics (China)
Mansour, 2008 [61]	Iraq	2007	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	≥20	43.2	43	1,2	FPG ≥ 7.0 mmol/l	3,4	Unspecified
Mbanya, 1997 [62]	Cameroon	NA	Sub-national, community	Household	Cross-sectional	Census	Population	24–74	45.4	41	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Mbanya, 1999 [63]	Cameroon	1995	Sub-national, community	Household	Cross-Sectional	Local rural census performed	Population	25–74	50.0	49	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	70 km from Yaounde (urban)
Motala, 2008 [64]	S Africa	1999–2000	Sub-national, community	Household	Cross-sectional	Census	Cluster	≥16	46.9	19	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Namperumalsamy, 2009 [25]	India	2005–6	Sub-national, community	Household	Cross-sectional	Unspecified	Cluster	≥30	NA	47.9	1,2	FPG ≥ 7.0 mmol/l	2,3,4	Semi-rural
Oladapo, 2010 [66]	Nigeria	2002–5	Sub-national, community	Household	Cross-Sectional	Unspecified	Simple	18–64	42.1	43.7	1,2	FPG ≥ 7.0 mmol/l	2,3,4	Agriculture and livestock main economic activities; mean income < $1k US

Table 1 (*Continued*)

Author, year	Country	Study period	Study	Setting	Design	Sample frame	Sample method	Age range	Mean age	Male (%)	DM type	Diagnostic method[b]	Quality criteria met[a]	Description of rural area used
Patandin, 1994 [67]	India	1990	Sub-national, community	Household	Cross-sectional	Rural unit for Health and Social Affairs (census-like)	Simple	≥40	54.0	41.1	2	OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Prabhakaran, 2007 [68]	India	NA	Sub-national, community	Household	Cross-sectional	Unspecified	Stratified	35–64	46.3	43	1,2	FWBG ≥ 6.1 mmol/l	3,4	Based on guidelines of the registrar general of Census of India
Rahim, 2007 [69]	Bangladesh	2004	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	≥20	37.2	40.1	2	FWBG ≥ 6.1 mmol/l	2,3,4	35 miles outside of Dhaka city
Rahman, 2007 [6]	Bangladesh	2004	Sub-national, community	Household	Cross-sectional	Census	Simple	≥20	38.9	31	2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	50 km outside Dhaka city
Ramachandran, 1992 [70]	India	1988–9	Sub-national, community	Community Hall	Cross-sectional	Census	Simple	≥20	41.0	50	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	40 miles outside of Madras
Ramachandran, 1999 [71]	India	1997	Sub-national, community	Household	Cross-sectional	Census	Simple	≥20	37.5	45.8	2	OGTT ≥ 11.1 mmol/l	2,3,4	97% of population engaged in manual labor; population size 3444 adults according to census
Ramachandran, 2004 [72]	India	2003	Sub-national, community	Household	Cross-sectional	Census	Unspecified	≥20	41.0	41	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Classified per directorate of Census of India
Sadikot, 2004 [15]	India	1999–2002	National	Household	Cross-sectional	Done by independent polling agency (unspecified)	Multi-stage	≥25	NA	46.9	2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	1,2,3,4	Rural defined as population < 100,000
Sasaki, 2005 [73]	Nepal	1990	Sub-national, community	Household	Cross-sectional	Census	Population	≥21	NA	51.2	1,2	FPG ≥ 7.0 mmol/l	3,4	Unspecified
Satman, 2002 [74]	Turkey	1997–8	National	Clinic	Cross-sectional	Health registry	Simple	≥20	NA	45	1,2	OGTT ≥ 11.1 mmol/l	1,2,3,4	Unspecified
Sayeed, 1995 [75]	Bangladesh	1992	Sub-national, community	Household	Cross-sectional	Unspecified	Cluster	≥17	38.0	45	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Villages; maintained livelihood fishing, agrarian, day laborers
Sayeed, 1997 [76]	Bangladesh	NA	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	≥20	41.4	60.4	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Farmers, agrarian; outside of Dhaka
Sayeed, 2003 [77]	Bangladesh	1999–2000	Sub-national, community	Clinic	Cross-sectional	Census	Cluster	≥20	37.9	47.1	2	FPG ≥ 7.0 mmol/l	2,3,4	Livelihood primarily related to agriculture
Shera, 1995 [78]	Pakistan	1994	Sub-national, community	Household	Cross-sectional	Census	Stratified	≥25	42.4	40	1,2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Traditional lifestyle; population = 80,000
Shera, 1999 [79]	Pakistan	1995	Sub-national, community	Clinic	Cross-sectional	Census	Cluster	≥25	43.5	32.5	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Outside of Peshwar
Shera, 1999 [80]	Pakistan	1995	Sub-national, community	Household	Cross-sectional	Unspecified	Cluster	≥25	45.1	20	2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Silva-Matos, 2011 [81]	Mozambique	2005	National	Household	Cross-sectional	Census	Cluster	25–64	NA	40	1,2	FPG ≥ 7.0 mmol/l	1,2,3,4	Unspecified
Singh, 1998 [82]	India	1991	Sub-national, community	Household	Cross-sectional	Unspecified	Cluster	25–64	NA	50.8	2	OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified
Sobngwi, 2002 [83]	Cameroon	NA	Sub-national, community	Household	Cross-sectional	Census	Simple Random	≥15	46.8	40.1	1,2	FWBG ≥ 6.1 mmol/l	2,3,4	Unspecified

Suriyawongpaisal, 2003 [84]	Thailand	2000	National	Household	Cross-sectional	Local government registers	Unspecified at provincial/upper level; but simple at lower level	≥35	NA	44.3	1,2	FPG ≥ 7.0 mmol/l	1,3,4	Development criteria by the Dept of Community Development of the Thai Ministry of the interior
Swai, 1991 [85]	Tanzania	NA	Sub-national, community	School	Cross-sectional	Census	Population	≥15	NA	NA	1,2	OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Swai, 1993 [86]	Tanzania	NA	Sub-national, community	Household	Cross-sectional	Census	Population	≥15	NA	43.2	1,2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Unspecified
Taylor, 1991 [87]	Vanuatu	1985	Sub-national, community	Household	Cross-sectional	Census	Population	≥20	NA	41.6	1,2	FPG ≥ 7.8 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Remote yet accessible by Vanuatu
Tazi, 2003 [88]	Morocco	2000	National	Household	Cross-sectional	Census	Cluster	≥20	NA	41.9	1,2	FPG ≥ 7.0 mmol/l	1,2,3,4	Unspecified
Tian, 2009 [14]	China	2004	Sub-national, provincial	Unspecified	Cross-sectional	Census	Population	≥35	50.7	47.4	1,2	FPG ≥ 7.0 mmol/l	2,3,4	Unspecified
Van Der Sande, 2000 [89]	The Gambia	1996–7	Sub-national, community	Household	Cross-sectional	Demographic surveillance program (20/40 villages taking part were randomly selected)	Stratified cluster	≥15	37.7	37.2	1,2	OGTT ≥ 11.1 mmol/l	2,3,4	Vast majority involved in subsistence farming
Wang, 2009 [90]	China	2006–7	Sub-national, provincial	Household	Cross-sectional	Census	Multi-stage, cluster	≥30	51.7	44.7	1,2	FPG ≥ 7.0 mmol/l	2,3,4	90% of population are farmers
Wei, 2010 [91]	China	2005	Sub-national, community	Unspecified	Cross-sectional	Unspecified	Multi-stage, cluster	>20	NA	50	2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Defined to reflect the livelihood primarily related to agricultural and agrarian activities
Zahid, 2008 [5]	Pakistan	2006	Sub-national, community	Household	Cross-sectional	Unspecified	Simple	≥20	44.2	34.9	1,2	FPG ≥ 7.0 mmol/l, OGTT ≥ 11.1 mmol/l	3,4	Area of 250 villages
Zaman, 2001 [92]	Bangladesh	1996	Sub-national, community	Household	Cross-sectional	Census	Simple	≥18	37.0	46.7	1,2	FPG ≥ 7.8 mmol/l	3,4	Outside of Dhaka city, agricultural area
Zargar, 2000 [93]	India	NA	Sub-national, community	Household	Cross-sectional	Census	Multi-stage	≥40	NA	56.5	2	FPG ≥ 6.7 mmol/l, OGTT ≥ 11.1 mmol/l	2,3,4	Unspecified

[a] 1 = national representativeness, 2 = no non-response bias, 3 = standard data collection methods, 4 = appropriate statistical methods.
[b] FPG, fasting plasma glucose level, FWBG, fasting whole blood glucose level, OGTT, 2-h post-75 g load plasma glucose level.

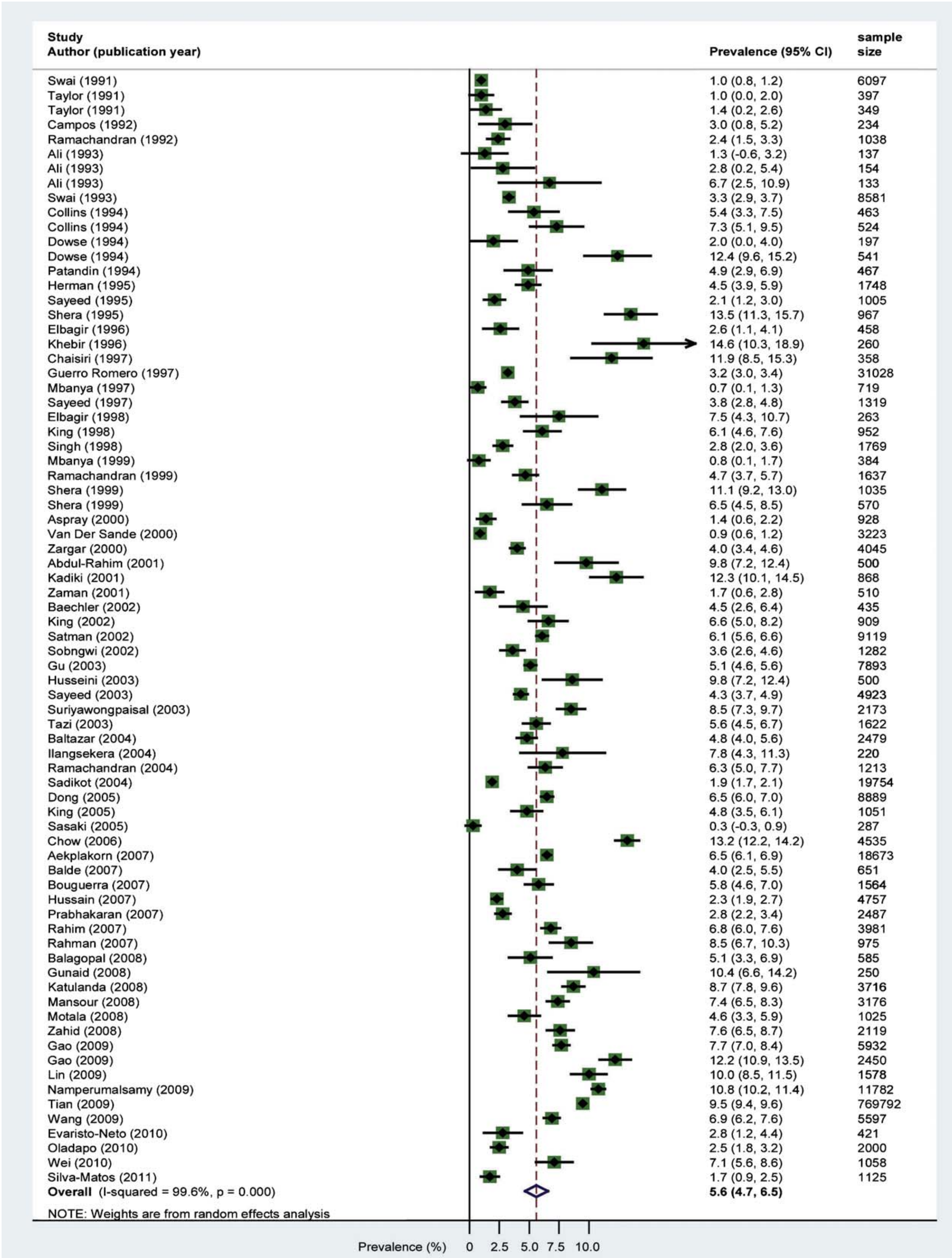

Fig. 2 – Diabetes prevalence studies (*n* = 76) in rural populations of different LMICs (arranged by publication year chronologically from 1990 to 2011). Black diamonds indicate diabetes prevalence for each study; the length of green rectangles indicates the weight of each study in random effect analysis; horizontal lines indicate 95% confidence interval; and unfilled diamond indicates the overall pooled prevalence estimate. Red-dashed vertical line indicates the overall prevalence estimate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

search in October 2010 and 109 from the update search in May 2011). A total of 70 publications (68 from the original search and 2 from the update search) which included 76 cross-sectional surveys (74 from the original search and 2 from the update search) comprising 1,000,823 subjects met inclusion criteria. There were 23 studies originating in East Asia & the Pacific, three studies from Europe & Central Asia, three studies from Latin America & the Caribbean, eight studies from the Middle East & North Africa, 25 studies from South Asia, and 14 studies from Sub-Saharan Africa. Full details and quality assessments of all included studies are shown in Table 1.

Overall, the pooled prevalence of diabetes in rural areas of LMICs over the 25-year period was 5.6% (4.6 to 6.6) (Fig. 2). Pooled prevalence estimates varied by year during which the study was conducted (Fig. 3). Rural prevalence increased from 1.8% (1.0–2.6) in the 1985–1989 period, to 5.0% (3.8–6.3) for 1990–1994, to 5.2% (4.1–6.2) for 1995–1999, to 6.4% (5.1–7.7) for 2000–2004, and to 8.6% (6.4–10.7) for 2005–2010 ($p = 0.001$ for secular trend). Furthermore, direction of secular trend of diabetes prevalence estimates using publication year was consistent with the findings when study to conducted year was used (Supplementary Fig. 1).

The pooled prevalence estimates also varied by region (Fig. 4). The Middle East & North Africa region had the highest rural diabetes prevalence (7.7%; 6.2–9.3) followed by East Asia & the Pacific (6.6%; 5.4–7.8), Europe & Central Asia (6.1%; 5.7–6.6), and South Asia (5.7%; 4.4–7.0), respectively. The lowest overall pooled prevalence estimates were found in Latin America & the Caribbean (3.2%; 3.0–3.4) and sub-Saharan Africa (2.4%; 1.7–3.0). When further stratified by sex (using 51 studies providing prevalence data separately for men and women), the highest diabetes pooled prevalence estimates, both for men and for women, were still in the Middle East & North Africa [9.9% (6.7–13.2) and 10.0% (7.1–12.9), respectively] and the lowest prevalence estimate was noted in Sub-Saharan Africa [2.5% (1.4–3.7) and 2.2% (1.2–3.3), respectively].

Rural diabetes prevalence estimates over the 25-year period was estimated for each country (supplementary Fig. 2). The highest prevalence estimates were found in Libya (12.3%; 10.1–14.5), Yemen (10.4%; 6.6–14.2), Pakistan (9.6%; 6.7–12.5), Palestine (9.2%; 7.4–11.0), China (8.1%; 6.5–9.7), and Sri Lanka (8.6%; 7.8–9.5). The lowest prevalence was found in Nepal (0.3%; 0.3–0.9), the Gambia (0.9%; 0.6–1.2), and Vanuatu (1.2%; 0.4–1.9).

4. Sensitivity analysis

Sensitivity analyses comparing studies with appropriate statistical methods and limited nonresponse bias showed no difference in the overall prevalence estimate observed. Additionally, isolating eight studies that were considered the highest quality studies on the basis of representativeness to the national rural population, the estimated pooled prevalence of diabetes (4.7%; 2.7–6.7) was not statistically different from the overall pooled prevalence (5.6%; 4.6–6.6). Likewise, the pooled prevalence after excluding the four studies in the first time period from 1985 to 1989 (5.9%; 5.0–6.9) was similar to the overall pooled prevalence, and the trend for the pooled rural prevalence in the remaining periods remained significant ($p = 0.005$).

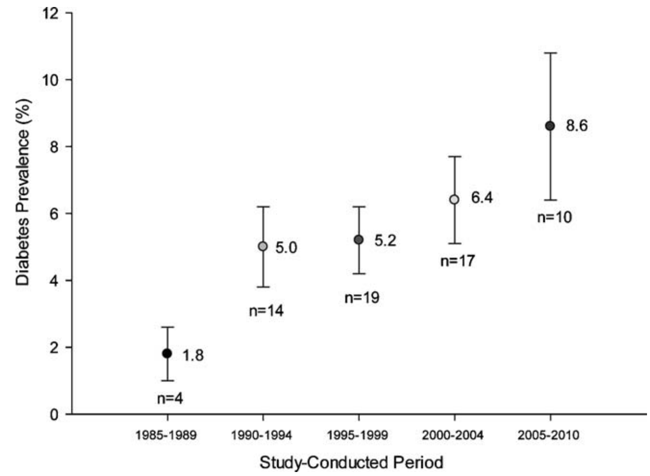

Fig. 3 – Trend of diabetes prevalence based on the year during which the study was conducted from 1985 to 2010 ($n = 64$). Vertical lines indicate 95% confidence intervals.

The Galbraith Plot revealed that the populations studied by Tian and colleagues [14], Sadikot and colleagues [15], and Guerrero Romero and colleagues [16] introduced most heterogeneity. We excluded these studies in our sensitivity analyses, and the pooled prevalence estimate was 5.6% (4.9–6.3), no difference from the estimate when these studies were included.

To assess the impact of lowered FPG thresholds for diabetes diagnosis, we excluded 15 studies using the old diabetes criteria in our sensitivity analyses, and the diabetes prevalence estimate among the remaining studies was 5.8% (4.7–6.9). Moreover, to verify the assumption that the prevalence of diabetes is largely driven by type 2 diabetes, we performed a sensitivity analysis excluding the studies not specifying the diabetes type, and the prevalence estimate was 5.6% (4.8–6.4).

Accounting for sex and age, sensitivity analysis remained robust. We examined sex as a possible source of heterogeneity, and among 49 studies providing prevalence values for men and women, the pooled prevalence was 5.4% (4.4–6.5) for men and 5.4% (4.0–6.8) for women. We also assessed age as a possible source of heterogeneity. Out of 47 studies reporting mean age, there were nine studies that were conducted in older populations (mean age $\geq$ 50 years). Excluding these nine studies, the pooled prevalence estimate was 5.3% (4.5–6.2).

5. Discussion

Our systematic review provides insight into the current magnitude, geographical distribution, and secular trend of diabetes in rural areas of LMICs. The pooled prevalence of diabetes in rural populations in all LMICs is high (5.6%) and has quintupled over the past twenty-five years, with no difference in prevalence between men and women. There were significant differences in prevalence across rural regions of the world, varying from 7.7% in the Middle East & North Africa to 2.4% in Sub-Saharan Africa, similar to the estimates reported in review studies of rural prevalence in West Africa [17] and Sub-Saharan Africa [18].

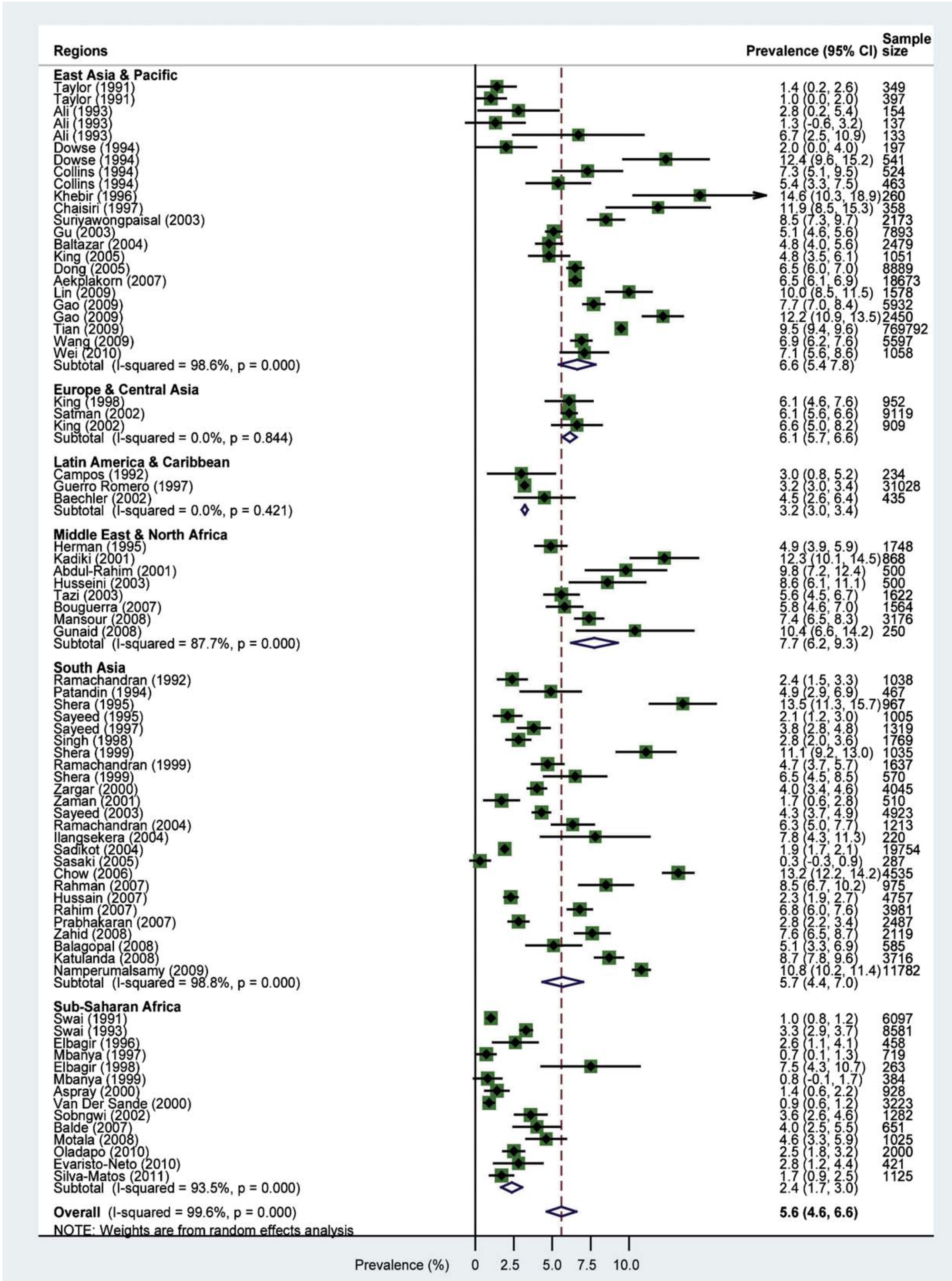

Fig. 4 – Listing of diabetes prevalence studies of rural populations of LMICs according to different World Bank-classified regions (arranged by publication year chronologically from 1990 to 2011). Black diamonds indicate diabetes prevalence for each study; the length of green rectangles indicates the weight of each study in random effect analysis; horizontal lines indicate 95% confidence interval; and unfilled diamond indicates regional or overall pooled prevalence estimate. Red-dashed vertical line indicates the overall prevalence estimate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Several epidemiologic studies have reported high prevalence of diabetes in rural areas of LMICs [4–6] with a recent study from China [3] estimating rural prevalence close to 9%. In our review, the pooled prevalence of diabetes from 2005 to 2010 in rural parts of LMICs was similarly 8.6%. Of particular concern, we noted a staggering four-fold increase in prevalence over just 25 years, a pattern observed in a recent review study of diabetes prevalence in India [19]. The International Diabetes Federation (IDF) estimates from 2009 project a 54% increase in world-wide prevalence of diabetes in the coming two decades (from 285 million in 2010 to 438 million in 2030) [1]. However, our results suggest that increases in the number of people with diabetes may be even more dramatic, if one considers the rapid emergence of diabetes across populated rural areas of LMICs [7]. Life expectancy in LMICs has been increasing. However, without an accompanying rise in incidence, it is highly unlikely that it could fully justify the four-fold increase in diabetes prevalence over the twenty-year period. It has been postulated that increases in rural diabetes prevalence reflect rapid changes in lifestyle that are becoming increasingly pervasive in LMIC rural areas [20,21]. Indeed, increasing use of motorized vehicles (e.g., driving a tractor versus manually plowing the fields, riding a moped or motorcycle versus riding a bicycle) and mechanized labor have contributed to changing physical activity patterns in these settings [21,22]. However, further investigation is required to isolate the diabetes risk factors that are specific to rural inhabitants, and also determine the underlying reasons for regional variation. Identifying the factors associated with increased risk or protection from diabetes (as in the lowest-prevalence regions) may be invaluable in designing appropriate interventions.

One of the challenges of accurately estimating the rural prevalence of diabetes across many countries and regions of the world is that there is currently no universal definition of what constitutes a "rural population". In some studies, rural areas were typically small villages in remote locations, far from cities, and comprised of less than two hundred inhabitants [23,24]. However, in other studies, rural areas were defined more liberally to include areas close to a city, comprising of tens [15,16,22,23] or even hundreds of thousands of inhabitants [14–16,25,26]. We recommend that consensus be reached regarding a universal definition of the term "rural region." As the world urbanizes globally and rapidly [1,27], definitions chosen should adequately capture the many non-urban regions with significant "rural" characteristics (e.g., occupation and lifestyle patterns). As such, heterogeneity in the definition of "rural population" across studies could be a potential source of misclassification and could have affected our estimates.

In analyzing secular trends of rural prevalence of diabetes, there is often a delay from the time when the study was conducted to when the results are published, which could be as long as five years or more. Therefore, we estimated the prevalence and trend according to the year during which the study was initiated. Compared to a moderate doubling of prevalence when analyzed by publication year, we found four-fold increase in prevalence from 1985–1989 to 2005–2010 when analyzed according to the year in which the studies were conducted. Although several studies included in this review did not provide the date during which the study was done, we contacted the authors for this information and were able to incorporate 64 out of 76 studies for this analysis. The scarce number of studies in the 1985–1989 period may be a reflection of inadequate attention to the problem as the rural diabetes prevalence estimate was small (1.8%) for that period. However, from 1985–1989 to 2005–2010, there has been a noticeable increase in the number of studies devoted to estimating rural prevalence of diabetes in LMICs, possibly reflecting increased attention. In terms of availability of data for the periods examined, although there were just 10 studies in the 2005–2010 period, this may simply reflect the lag time until publication, especially for those that were undertaken closer to 2010.

Our study had a number of other limitations, some of which are related to the nature of the literature from which the data were collected. The quantity and quality of data available for different regions of the world varied considerably, with several regions exhibiting serious scarcities of data. In Europe & Central Asia as well as the Latin America & Caribbean regions, only three high-quality studies were available in each region in the last two decades, which may indicate that the prevalence estimates in these regions were not reflective of the true prevalence of each. This result is in sharp contrast to the East Asia & Pacific and South Asia regions, which had 23 and 25 studies, respectively, over the same time period. As evidenced by this review, diabetes prevalence is growing fast in rural parts of LMICs. The observed trends and gaps in data point to the importance of improving data collection systems that apply uniform definitions and measures, and monitor trends across all regions of the world. Aligned with this important realization, surveillance has indeed been identified as a high priority by WHO [28]. Secondly, our performing a unified analysis on heterogeneous studies may be another limitation. However, despite the heterogeneity, our estimates describe broad patterns to provide the overall picture and highlight the need for organized surveillance systems to more accurately monitor trends.

Since the studies reviewed spanned a 25-year period, some of the earlier studies used older diagnostic criteria [29], using a higher threshold level of FPG for detection, and this may have resulted in underestimation of the prevalence of diabetes, as compared to currently accepted criteria [11]. Additionally, there was variability in age range among the studies we reviewed, which may have affected the pooled estimate. However, our sensitivity analyses suggest that the prevalence estimates remained close to the original estimate of 5.6% after accounting for varying diagnostic criteria or mean age. Another limitation is that we only primarily used studies available in English. However, we utilized available technology to translate studies in foreign languages and obtained three additional studies for inclusion.

The majority of the studies included in this review did not specify the type of diabetes that was studied. However, given that type 2 diabetes accounts for over 90% of people with diabetes in the world [2], our overall estimates of diabetes prevalence and four-fold increase in prevalence over a 25-year period are almost surely predominantly driven by type 2 diabetes.

These limitations aside, this review quite conclusively shows that diabetes prevalence in rural areas of LMICs is consistently growing on a global scale. The prevalence estimates from our meta-analysis were produced based on a rigorous process where stringent inclusion criteria and quality assessments were applied. Therefore, they represent only the randomly selected samples from high-quality studies, leading us to comfortably conclude that rural prevalence is truly higher and rising faster than previously reported [1].

More than 80% of the estimated global expenditures for diabetes occur in the world's economically richest countries, while over 70% of people with diabetes live in LMICs [1], where awareness of chronic diseases is extremely low [30]. In addition to improving awareness, however, financial and physical access to prevention and healthcare services is critical, for risk factor control and routine examinations (e.g., fundoscopic exams, foot exams) are crucial toward reducing the risk of progression to debilitating complications (e.g., blindness, amputation) for people with diabetes. Models of diabetes prevention interventions may have to be adapted to suit the target populations. For example, in order to overcome enormous access barriers in rural areas, telemedicine vans have been used in India to travel to isolated rural communities in Tamil Nadu to screen for diabetes and complications [31]. Access to care to implement diabetes prevention and control will require a combination of garnering political will, resources, and novel implementation strategies to reach those at-risk and affected, promote uptake and maintenance, and ensure long-term effectiveness, acceptability, and sustainability of these initiatives.

While there is appropriate attention being devoted toward the increase in diabetes risk among migrants to urban areas from rural areas in LMICs [32], our review highlights the need for equal attention to rural areas of LMICs themselves. Diabetes prevalence is high and rapidly rising among rural populations in LMICs, much faster than the IDF's projected burden of diabetes for the next two decades. With morbidity, mortality, and economic impacts of lost earnings increasing concurrently, diabetes in rural populations of LMICs represents a major challenge in global public health. There is a clear mandate to invest in surveillance, translation of diabetes prevention, and affordable, innovative models of healthcare access and systems to stem the growing burden of diabetes in LMICs.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.diabres.2011.12.001.

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