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Indicators of optimal diabetes care and burden of diabetes complications in Africa: a systematic review and meta-analysis

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ABSTRACT

Objective Contemporary data on the attainment of optimal diabetes treatment goals and the burden of diabetes complications in adult populations with type 2 diabetes in Africa are lacking. We aimed to document the current status of attainment of three key indicators of optimal diabetes care and the prevalence of five diabetes complications in adult African populations with type 2 diabetes.

Methods We systematically searched Embase, PubMed and the Cochrane library for published studies from January 2000 to December 2020. Included studies reported any information on the proportion of attainment of optimal glycated haemoglobin (HbA1c), blood pressure (BP) and low-density lipoprotein cholesterol (LDLC) goals and/or prevalence of five diabetes complications (diabetic peripheral neuropathy, retinopathy, nephropathy, foot ulcers and peripheral arterial disease). Random effect model meta-analysis was performed to determine the pooled proportion of attainment of the three treatment goals and the prevalence of five diabetes complications.

Results In total, 109 studies with a total of 63 890 participants (53.3% being females) were included in the meta-analysis. Most of the studies were conducted in Eastern African countries (n=44, 40.4%). The pooled proportion of attainment of an optimal HbA1c, BP and LDLC goal was 27% (95% CI 24 to 30, I^2=94.7%), 38% (95% CI 30 to 46, I^2=98.7%) and 42% (95% CI 32 to 52, I^2=97.4%), respectively. The pooled prevalence of diabetic peripheral neuropathy, retinopathy, diabetic nephropathy, peripheral arterial disease and foot ulcers was 38% (95% CI 31 to 45, I^2=98.2%), 32% (95% CI 28 to 36, I^2=98%), 31% (95% CI 22 to 41, I^2=99.3%), 19% (95% CI 12 to 25, I^2=98.1%) and 11% (95% CI 9 to 14, I^2=97.4%), respectively.

Conclusion Attainment of optimal diabetes treatment goals, especially HbA1c, in adult patients with type 2 diabetes in Africa remains a challenge. Diabetes complications, especially diabetic peripheral neuropathy and retinopathy, are highly prevalent in adult populations with type 2 diabetes in Africa.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ To our knowledge, it is the first systematic review and meta-analysis to simultaneously investigate the status of attainment of the three key diabetes treatment goals and the burden of five common diabetes complications in an adult indigenous African population with type 2 diabetes.
⇒ The systematic review and meta-analysis included a large number of studies that assessed the extent of attainment of diabetes treatment goals and the prevalence of diabetes complications based on recommendations or definitions by internationally recognised associations.
⇒ There was high heterogeneity among the studies included in the meta-analysis.
⇒ A relative number of studies included in the meta-analysis had low to moderate quality on assessment.

INTRODUCTION

Globally, the burden of diabetes mellitus (DM) continues to exponentially rise to epidemic proportions, disproportionately affecting low-income and middle-income countries. The recent 2021 International Diabetes Federation (IDF) estimates show that about 24 million adults (1 in 22 adults) live with DM in Africa. The IDF also predicts that the greatest future increase in the prevalence of DM will occur in Africa because of the predicted ageing of Africa's currently very young populations, as well as increasing urbanisation and associated lifestyle changes.[1] This will ultimately lead to an immense strain

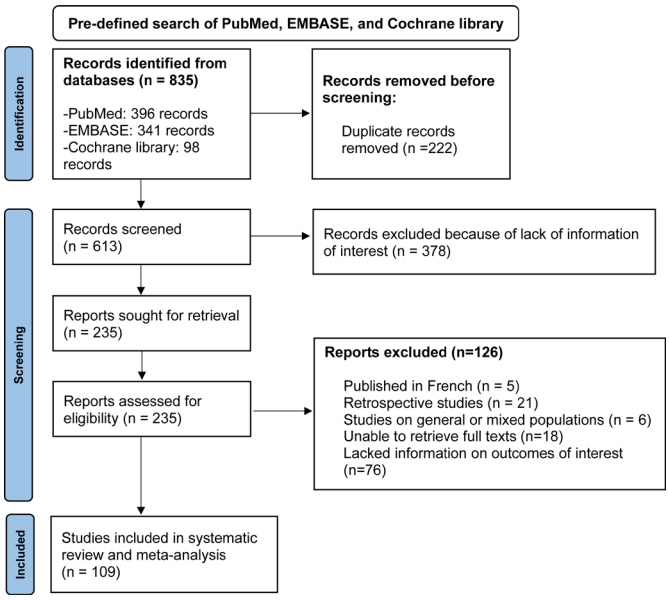

Figure 1 PRISMA flow diagram of selection of eligible studies. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

on weak healthcare systems that are poorly structured and inadequately financed to manage non-communicable diseases (NCDs) like DM.[2]

In addition, the rates of undiagnosed DM continue to increase in Africa. Among the IDF regions, Africa has the highest proportion of undiagnosed diabetes: about 54% of all cases.[1] The majority of patients are diagnosed late with coexisting debilitating complications, and suboptimal diabetes care remains common in most clinical settings in Africa.[3] This could be explained by low awareness about DM, healthcare systems that are structured mainly to manage communicable diseases as opposed to NCD, low screening rates of DM to ensure early diagnosis, low availability of affordable essential diagnostic tests and medicines for DM and knowledge–practice gaps among healthcare practitioners.[2 4–6]

Published diabetes treatment guidelines by most international organisations like the IDF and American Diabetes Association (ADA) recommend targets of glycated haemoglobin (HbA1c) level of <7% (53 mmol/mol), blood pressure (BP) <140/90 mm Hg and low-density lipoprotein cholesterol (LDLC) <2.6 mmol/L (100 mg/dL) as key indicators of optimal diabetes care.[7–9] Attainment of these treatment goals in diabetes care ultimately translates to reduced risk of onset and progression of diabetes complications and mortality.

Despite the increasing burden of DM and its related complications, late diagnosis of diabetes and prevalent suboptimal diabetes care in clinical settings in Africa, there is an information gap regarding the current status of attainment of the recommended diabetes treatment goals and the prevalence of common diabetes complications to inform targeted strategies or interventions to reduce diabetes-related morbidity and mortality. This systematic review and meta-analysis aimed to document the proportion of attainment of optimal HbA1c, BP and LDLC goals and the prevalence of five diabetes complications (diabetic peripheral neuropathy, nephropathy, retinopathy, foot ulcers and peripheral arterial disease) in adult native populations with type 2 diabetes in Africa.

METHODS

This systematic review and meta-analysis was conducted according to the criteria outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[10] The PRISMA checklist is available as an online supplemental table 1. The study protocol was registered in the PROSPERO International Prospective Register of systematic reviews (CRD42020215576).

Search strategy

We searched Embase, PubMed and the Cochrane library for published studies from January 2000 to December 2020. The following search terms were used after discussion with a medical librarian: "Quality of diabetes care" OR "Indicators of diabetes care" OR "status of diabetes care" OR "diabetes care" OR "glycaemic control" OR "blood pressure control" OR "lipid profile control" OR "screening of diabetes complications" OR "diabetes complications" OR "screening for diabetic retinopathy" OR "screening for diabetic peripheral nephropathy" OR screening for diabetic neuropathy" OR screening for diabetic foot ulcers OR "screening for peripheral arterial disease" OR "prevalence of diabetic retinopathy" OR "prevalence of diabetic peripheral nephropathy" OR "prevalence of diabetic peripheral neuropathy" OR "prevalence of diabetic foot ulcers" OR "prevalence of peripheral arterial disease", AND "type 2 diabetes mellitus" OR "type 2 diabetes" AND Algeria OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR Cameroon OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR "Democratic Republic of Congo" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea Bissau" OR "Ivory Coast" OR "Cote d'Ivoire" OR Kenya OR Lesotho OR Liberia OR Libya OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR "South Africa" OR "South Sudan" OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR Zaire OR Zambia OR Zimbabwe OR "Central Africa" OR "West Africa" OR "Western Africa" OR "East Africa" OR "Eastern Africa" OR "North Africa" OR "Northern Africa" OR "Southern Africa" OR "sub Saharan Africa" OR "sub-Saharan Africa" OR Africa.

In addition, references of included articles were handsearched for any other original articles. The search and selection were restricted to studies written only in the English language.

Table 1 General characteristics of all participants (n=63 890) included in the systematic review and meta-analysis

Characteristic	Cumulative value	Number of studies
Age in years (mean±SD)	54.9±4.7	88
Gender – females (%, 95% CI)	55.3, 52.7 to 57.8	101
Smokers (%, 95% CI)	9.9, 0.5 to 55.6	44
Participants on OHA (%, 95% CI)	65.0, 34.0 to 96.6	51
Participants on insulin (%, 95% CI)	31.3, 26.3 to 36.2	52
Participants on lipid-lowering agents (%, 95% CI)	25.7, 0.5 to 86.7	14
Participants on anti-hypertensive agents (%, 95% CI)	73.3, 64.1 to 82.5	18
BMI in kg/m^2 (mean±SD)	27.9±0.5	40
HbA1c in % (mean±SD)	9.0±1.5	40
HbA1c in mmol/mol (mean±SD)	75.0±1.5	40

BMI, body mass index; HbA1c, glycated haemoglobin; OHA, oral hypoglycaemic agents.

Study selection criteria

The preliminary screening of titles and abstracts to identify potentially eligible articles was done by two independent reviewers (NC and DK). This was followed by removing all duplicates. After the initial screening, full texts of the potentially eligible studies were retrieved and closely reviewed for eligibility.

The inclusion criteria of studies were: cross-sectional, cohort or randomised controlled trials published between January 2000 and December 2020 in English language, studies reporting any data on proportion of adult patients with type 2 diabetes who attained the recommended optimal HbA1c, BP or LDLC targets and residing in African countries and studies reporting data on any of prevalence of diabetic nephropathy, peripheral neuropathy, retinopathy, foot ulcers or peripheral arterial disease in adult patients with type 2 diabetes in African countries.

Any disagreements that arose were resolved by consensus. We excluded retrospective studies, case series and reports, studies published in languages other than English and studies whose full texts could not be retrieved.

Data extraction

After identifying the eligible original studies, they were collated and sent to additional reviewers to extract the relevant study information using a Microsoft Excel 2016 form. The information of interest that was extracted from the eligible studies included: the last name of the first author and year of publication, country(ies) and region(s) of Africa where the study was conducted, type of study design, number of study participants, the mean age of study participants, the proportion of female participants, the proportion of participants with a current or history of smoking, the proportion of participants on oral hypoglycaemic agents, insulin, lipid-lowering agents (statins) and antihypertensive agents, mean body mass index (BMI) and HbA1c of study participants, the proportions of participants with optimal HbA1c, BP and LDLC targets and the prevalence of diabetic nephropathy, peripheral neuropathy, retinopathy, foot ulcers and peripheral arterial disease.

Operational definitions

All included studies defined optimal targets of HbA1c, BP and LDLC as <7% (53 mmol/mol), <140/90 mm Hg and <2.6 mmol/L or 100 mg/dL, respectively, as recommended by the IDF and ADA diabetes treatment guidelines.[9 11]

The definitions and measurements of diabetes complications greatly varied between studies. The following definitions were used for each diabetes complication by the various studies: micro/macroalbuminuria and/or an estimated glomerular filtration rate <60 mL/min/1.73 m^2 for the presence of diabetic nephropathy, signs and symptoms suggestive of peripheral neuropathy, use of neuropathy screening scores like neuropathy disability score, Michigan Neuropathy Screening Instrument, neuropathy symptom score and 10 g monofilament testing for the presence of diabetic peripheral neuropathy, presence of lesions like soft or hard exudates, cotton wool spots, microaneurysms, neovascularisation and retinal haemorrhages on funduscopy for diabetic retinopathy, presence of foot ulcers on clinical inspection for diabetic foot ulcers and the presence of measured ankle brachial index <0.9 using Doppler studies for peripheral arterial disease.

Assessment of quality of studies

The quality of all eligible studies included in the systematic review and meta-analysis was assessed using the Newcastle-Ottawa Scale (NOS).[12] This was done by two independent authors (NC and SNL). The total score of the adapted scale is eight stars. Studies with more than six stars were considered high quality, while those with 5 and 6 stars, and <5 stars were considered of moderate and low quality.

Study outcomes

The study outcomes were the pooled proportions of attainment of the recommended optimal HbA1c, BP

Table 2 Indicators of optimal glycated haemoglobin goal

Optimal glycated haemoglobin (HbA1c) goal (n=34 studies): **pooled rate of attainment of optimal HbA1c goal=27% (95% CI 24 to 30, I^2=94.7%, 95% CI 93.6 to 95.8) and I^2 after meta-regression: 56.3%)**
Attainment of the optimal HbA1c goal per region: **central: 20% (95% CI 16 to 23), Eastern: 23% (95% CI 15 to 34), Northern: 24% (95% CI 17 to 31), Southern: 31% (95% CI 28 to 34) and Western: 37% (95% CI 29 to 46)**

First author and year	Country(ies)	Region of Africa	No. of study participants	Mean age of participants	% of females	% with optimal HbA1c
Adentunji2006[60]	Nigeria	Western	50	–	–	52.0
Agboghoroma 2020[61]	Nigeria	Western	200	–	–	19.0
Akalu 2020[20]	Ethiopia	Eastern	378	–	38.6	40.7
Amod 2012[101]	South Africa	Southern	701	57.4	43.9	30.4
Amour 2019[21]	Tanzania	Eastern	238	57.2	65.7	9.2
Ashur 2016[84]	Libya	Northern	523	54.4	47.0	21.8
Attoye 2020[63]	Nigeria	Western	260	–	–	34.6
Awadalla 2017[87]	Sudan	Northern	424	–	49.3	15.6
Balogun 2011[64]	Nigeria	Western	40	59.4	62.5	52.5
Bentata 2015[88]	Morocco	Northern	637	58.5	62.3	30.1
Blum 2020[117]	DRC	Central	319	–	33.5	14.1
Cairncross 2017[104]	South Africa	Southern	203	–	72.5	31.3
Camara 2015[59]	Cameroon and Guinea Conakry	Central and Western	1267	58.0	61.0	26.0
Chadli 2016[90]	Morocco	Northern	498	58.0	62.4	26.8
Chamba 2017[23]	Tanzania	Eastern	119	58.1	49.6	39.3
Chetoui 2019[92]	Morocco	Northern	1456	56.2	73.4	33.7
Cohen 2010[105]	Malawi	Southern	620	52.2	60.1	36.0
Diaf 2017[93]	Algeria	Northern	210	55.6	65.0	51.4
Hall 2017[120]	Cameroon	Central	261	56.0	56.3	27.2
Iwuala 2015[71]	Nigeria	Western	100	59.9	62.0	45.0
Kibirige 2017[35]	Uganda	Eastern	425	–	67.0	26.5
Kimando 2017[36]	Kenya	Eastern	385	62.1	65.5	39.5
Kisozi 2017[37]	Uganda	Eastern	288	48.5	38.0	23.3
Mbwete 2020[44]	Tanzania	Eastern	161	63.9	67.1	49.7
Megallaa 2019[97]	Egypt	Northern	180	–	24.4	4.4
Molefe-Baikai 2018[110]	Botswana	Southern	289	50.7	66.1	29.4
Muddu 2019[46]	Uganda	Eastern	175	46.0	48.6	8.1
Muddu, 2016[45]	Uganda	Eastern	202	46.0	49.5	8.4
Mwebaze 2014[47]	Uganda	Eastern	146	53.9	48.6	19.2
Mwita 2019[111]	Botswana	Southern	500	58.9	66.0	32.3
Noor, 2016[98]	Sudan	Northern	387	–	49.6	15.0
Omar 2018[99]	Sudan	Northern	339	54.8	69.9	28.1
Sobngwi 2011[3]	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	2352	53.0	61.1	29.2
Uloko 2012[67]	Nigeria	Western	531	57.1	60.5	32.4

Table 3 Indicators of optimal blood pressure (BP) goal

Optimal BP goal (n=26 studies): **pooled rate of attainment of optimal BP goal=38% (95% CI 30 to 46, I^2=98.7%–95% CI 98.6 to 99.0), and I^2 after meta-regression: 95.4%).**
Attainment of the optimal BP goal per region: **Western: 31% (95% CI 20 to 43), Eastern: 40% (95% CI 24 to 57), Southern: 40% (95% CI 26 to 55), Central: 41% (95% CI 38 to 45) and Northern: 42% (95% CI 24 to 61).**

Author and year	Country(ies)	Region of Africa	No. of study participants	Mean age of participants	% of females	% with optimal BP
Abdissa *et al* 2020[18]	Ethiopia	Eastern	229	–	40.4	31.0
Agboghoroma *et al* 2020[61]	Nigeria	Western	200	–	–	30.0
Akalu *et al* 2020[20]	Ethiopia	Eastern	378	–	38.6	57.7
Amour *et al* 2019[21]	Tanzania	Eastern	238	57.2	65.7	21.7
Awadalla *et al* 2017[87]	Sudan	Northern	424	–	49.3	60.1
Balogun *et al* 2011[64]	Nigeria	Western	40	59.4	62.5	55.0
Chadli *et al* 2016[90]	Morocco	Northern	498	58.0	62.4	20.2
Chahbi *et al* 2018[91]	Morocco	Northern	300	–	93.0	32.6
Chisha *et al* 2017[24]	Ethiopia	Eastern	270	–	48.9	85.9
Cohen *et al* 2010[105]	Malawi	Southern	620	52.2	60.1	48.0
Hall *et al* 2017[5 120]	Cameroon	Central	261	56.0	56.3	43.0
Hayfron-Benjamin *et al* 2019[70]	Ghana	Western	206	52.9	68.9	37.9
Jingi *et al* 2015[121]	Cameroon	Central	407	54.2	41.8	40.4
Kahloun *et al* 2014[96]	Tunisia	Northern	2320	54.5	60.2	62.5
Kimando *et al* 2017[36]	Kenya	Eastern	385	62.1	65.5	50.4
Lewis *et al* 2018[107]	Zambia	Southern	921	56.0	45.0	46.6
Lumu *et al* 2017[39]	Uganda	Eastern	425	52.2	67.0	54.7
Magan *et al* 2019[41]	Uganda	Eastern	44	50.4	63.4	34.1
Megallaa *et al* 2019[97]	Egypt	Northern	180	–	24.4	37.8
Muddu *et al* 2016[45]	Uganda	Eastern	202	46.0	49.5	38.1
Mwebaze *et al* 2014[47]	Uganda	Eastern	146	53.9	48.6	1.5
Mwita *et al* 2019[111]	Botswana	Southern	500	58.9	66.0	54.2
Onakpoya *et al* 2015[77]	Nigeria	Western	133	–	48.1	24.1
Rotchford *et al* 2002[113]	South Africa	Southern	253	56.5	73.1	14.0
Sobngwi *et al* 2011[3]	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	2352	53.0	61.1	21.0
Uloko *et al* 2012[67]	Nigeria	Western	531	57.1	60.5	17.0

and LDLC goals and the pooled prevalence of diabetic nephropathy, peripheral neuropathy, retinopathy, foot ulcers and peripheral arterial disease in adult patients with type 2 diabetes in Africa.

Data analysis

All analyses were performed using STATA V.16.0 statistical software (Stata Corp, USA). The descriptive data of all eligible studies included in the systematic review and meta-analysis like age, gender, the proportion of participants on specific glucose-lowering agents, BMI and HbA1c were summarised using frequencies and 95% CIs and mean±SD.

For the continuous variables, the average estimated value was obtained from each of the studies, and this was used in the final analysis, while for the categorical variables, the proportions were estimated for each of the studies and used in the final analysis.

The pooled proportions of achievement of optimal HbA1c, BP and LDLC goals and the prevalence of diabetic nephropathy, peripheral neuropathy, retinopathy, foot ulcers and peripheral arterial disease were determined using a random effect model meta-analysis and presented

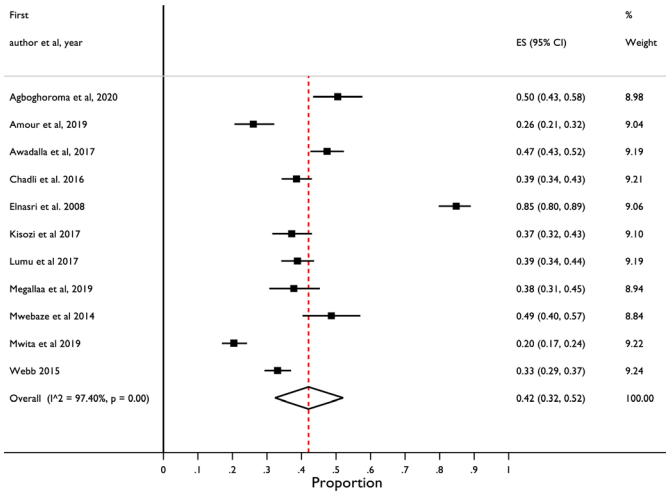

Figure 2 Forest plot summarising studies on the proportion of attainment of an optimal low-density lipoprotein cholesterol goal in percentage. ES, effect size.

in forest plots. The DerSimonian and Laird method was used for pooling random effects estimates.[13]

The heterogeneity of studies was assessed using the I^2 value and corresponding 95% CIs. Based on the Cochrane collaboration guide, the I^2 values of 0%–40%, 30%–60%, 50%–90% and 75%–100% were considered not important, moderate, substantial and considerable levels of heterogeneity, respectively.[14] To further explore heterogeneity effects across studies, we conducted a meta-regression analysis to assess whether the heterogeneity could be explained by the study level characteristics, that is, age, sex of participants and region, in which the study was conducted. The age, BMI and sex of the participants was defined as the estimated mean age and BMI of participants and the proportion of females from each of the study, respectively. The region of the study was defined as the area (Northern, Southern, Eastern, Western, and Central Africa) where the study was conducted. One effect measure per study was considered in the meta-regression. All the variables were included in the model together to assess for variability.

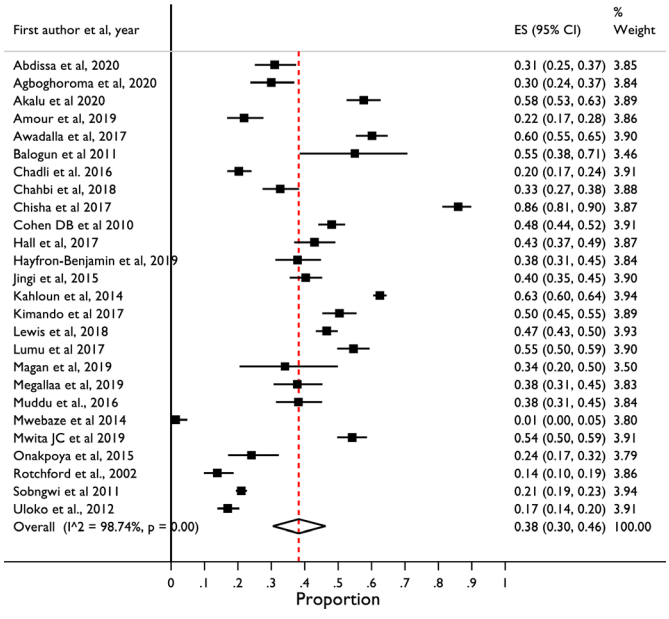

Figure 3 Forest plot summarising studies on the proportion of attainment of an optimal blood pressure goal in percentage. ES, effect size.

We assessed the presence of publication bias using the Egger test of bias with p<0.05 indicating significant publication bias.[15] A narrative review was also used to present the study results. Information about all included studies was also summarised in tables.

We also performed a sensitivity analysis based on the NOS scores of the studies (excluding moderate and low-quality studies) and compared the analysis with all the eligible studies and with only high-quality studies to identify any differences in the pooled estimates of the rates of attainment of optimal diabetes treatment goals and the prevalence of the five diabetes complications.

Patient and public involvement

The main research question and outcomes of interest of the systematic review and meta-analysis were informed by the need to understand the burden of diabetes complications in patients with type 2 diabetes in Africa and the extent of attainment of optimal diabetes care to inform strategies aimed to improve optimal management of diabetes in the region. Because it was a systematic review and meta-analysis, we did not involve patients in its design, recruitment and conduct.

RESULTS

Figure 1 summarises the article selection in a PRISMA flow diagram.

The literature search returned a total of 835 articles. From these, 222 duplicates were removed. Titles and abstracts of the remaining 613 articles were reviewed, and 235 articles were identified for full-text retrieval. Of the 235 articles, 126 were excluded, and the remaining 109 articles were included in this systematic review and meta-analysis. A total of 48 and 89 eligible studies contained information on optimal diabetes treatment goals and diabetes complications, respectively, while 28 studies reported information on both.

The 126 excluded articles included five studies published in French language, 21 retrospective studies, six studies with general populations (not entirely patients with type 2 DM), 18 studies whose full texts were unable to be retrieved and 76 studies that did not report outcomes of interest.

Characteristics of included studies

The majority of studies were performed in Eastern African countries (44, 40.4%).[3 16–58] The proportion of studies conducted in Western, Northern, Southern and Central Africa was 22% (n=24 studies),[3 59–80] 16.5% (n=18 studies),[81–99] 15.6% (n=17 studies)[100–116] and 8.3% (n=9 studies),[3 59 117–123] respectively. Three studies were

conducted in more than one region of Africa (Western, Central and Eastern).[3 58 59] Most of the studies were cross-sectional in design (100, 91.7%).

Considerable heterogeneity was noted across the studies with the I^2 value ranging from 97.4% to 99.3% for studies reporting the burden of diabetes complications and 94.7%–98.7% for studies reporting the extent of attainment of optimal diabetes treatment goals. However, on meta-regression after adjusting for age and sex of study participants, and region where each study was conducted, the heterogeneity based on I^2 of studies on the prevalence of diabetes complications decreased, ranging from 1.4% for studies on diabetic foot ulcers to 95.6% for studies on diabetic nephropathy. For studies on the proportion of attainment of optimal treatment goals, the heterogeneity also decreased, to 56.3%, 92.1% and 95.4%, for studies reporting optimal HbA1c, LDLC and BP goals.

Characteristics of study participants

Table 1 summarises the characteristics of all participants in the studies included in the systematic review and meta-analysis.

The studies had a total of 63 890 participants (ranging from 40 to 11 866) with 53.3% being female. The mean±SD age, BMI and HbA1c of the participants was 54.9±4.7 years (ranging from 40.5 to 63.9 years), 27.9±0.5 kg/m^2 (ranging from 20.6 to 42.9 kg/m^2) and 9.0±1.5% (ranging from 6.5% to 13.9%), respectively. Among the studies that reported data on the type of glucose-lowering therapies used by participants, treatment with oral hypoglycaemic agents, insulin, statins and antihypertensives was reported in about 65% (95% CI 34 to 96.6), 31.3% (95% CI 26.3 to 36.2), 25.7% (95% CI 0.5 to 86.7) and 73.3% (95% CI 64.1 to 82.5) of participants, respectively.

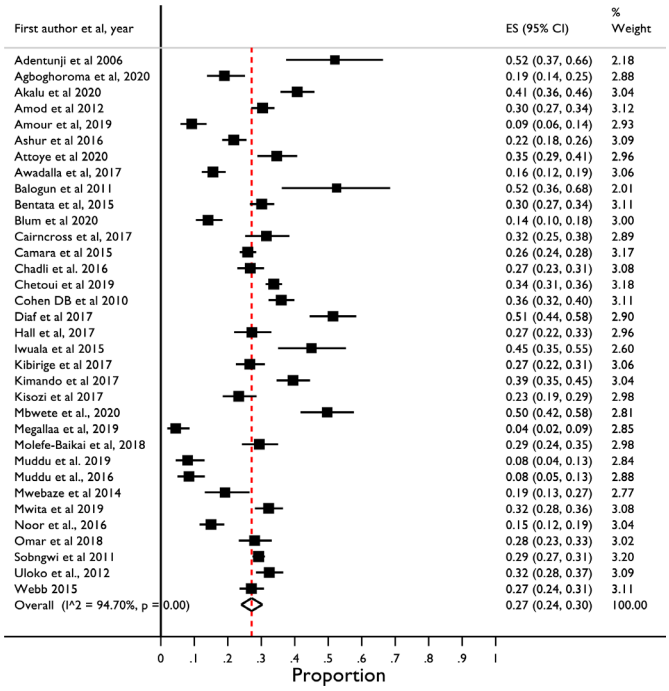

Figure 4 Forest plot summarising studies on the proportion of attainment of an optimal glycated haemoglobin goal in percentage. ES, effect size.

Assessment of study quality and publication bias

The assessment of the quality of studies and funnel plots assessing publication bias are summarised in online

Table 4 Indicators of optimal LDLC goal

Optimal LDLC goal (n=11 studies)
Pooled rate of attainment of optimal LDLC goal=42% (95% CI 32 to 52, I^2=97.4%–95% CI 96.5 to 98.1) and I^2 after meta-regression-92.1%).
Attainment of the optimal LDLC goal per region: **Southern: 27% (95% CI 24 to 30), Eastern: 37% (95% CI 30 to 45), Western: 51% (95% CI 43 to 58) and Northern: 53% (95% CI 32 to 74).**

Author and year	Country(ies)	Region of Africa	No. of study participants	Mean age of participants	% of females	% with optimal LDLC
Agboghoroma *et al* 2020[61]	Nigeria	Western	200	–	–	50.5
Amour *et al* 2019[21]	Tanzania	Eastern	238	57.2	65.7	26.0
Awadalla *et al* 2017[87]	Sudan	Northern	424	–	49.3	47.4
Chadli *et al* 2016[90]	Morocco	Northern	498	58.0	62.4	38.6
Chamba *et al* 2017[23]	Tanzania	Eastern	119	58.1	49.6	27.7
Elnasri *et al* 2008[94]	Sudan	Northern	250	52.0	62.0	84.8
Kisozi *et al* 2017[37]	Uganda	Eastern	288	48.5	38.0	37.0
Lumu *et al* 2017[39]	Uganda	Eastern	425	52.2	67.0	38.9
Megallaa *et al* 2019[97]	Egypt	Northern	180	–	24.4	37.8
Mwebaze *et al* 2014[47]	Uganda	Eastern	146	53.9	48.6	48.6
Mwita *et al* 2019[111]	Botswana	Southern	500	58.9	66.0	20.4

LDLC, low-density lipoprotein cholesterol.

Table 5 Prevalence of diabetic nephropathy

Prevalence of diabetic nephropathy (n=40 studies): **pooled prevalence=31% (95% CI 22 to 41, I^2=99.3% 95% CI 99.2 to 99.4) and I^2 after meta-regression: 95.6%).**
Prevalence of diabetic nephropathy per region: **Central: 22% (95% CI 9 to 39), Eastern: 25% (95% CI 10 to 43), Southern: 28% (95% CI 18 to 40), Northern: 38% (95% CI 14 to 65) and Western: 47% (95% CI 25 to 69).**

Author and year	No. of study participants	Country (ies)	Region of Africa	Mean age of participants	% of females	Prevalence of nephropathy, %
Abejew *et al* 2015[19]	216	Ethiopia	Eastern	45.0	42.6	2.2
Adeniyi *et al* 2020[100]	327	South Africa	Southern	–	70.3	24.5
Adentunji *et al* 2006[60]	50	Nigeria	Western	–	–	83.0
Ahmed *et al* 2017[82]	316	Sudan	Northern	58.0	41.5	40.2
Albalawi *et al* 2020[83]	159	Sudan	Northern	58.1	65.4	26.4
Alebiosu *et al* 2013[62]	342	Nigeria	Western	53.4	–	28.4
Amour *et al* 2019[21]	315	Tanzania	Eastern	57.2	65.7	72.2
Balogun *et al* 2011[64]	40	Nigeria	Western	59.4	62.5	90.0
Bello *et al* 2017[66]	358	Nigeria	Western	57.8	61.7	53.4
Bentata *et al* 2015[88]	637	Morocco	Northern	58.5	62.3	77.2
Blum *et al* 2020[117]	319	DRC	Central	–	33.5	38.6
Bouaziz *et al* 2012[89]	73	Tunisia	Northern	59.3	–	11.0
Chahbi *et al* 2018[91]	300	Morocco	Northern	–	93.0	26.3
Cohen *et al* 2010[105]	620	Malawi	Southern	52.2	60.1	34.7
Deribe *et al* 2014[27]	216	Ethiopia	Eastern	50.7	40.3	8.8
Dzudie *et al* 2012[118]	420	Cameroon	Central	56.7	51.0	15.9
Efundem *et al* 2017[119]	162	Cameroon	Central	55.3	67.3	14.2
Eghan *et al* 2007[69]	109	Ghana	Western	54.1	75.0	43.0
Fasil *et al* 2019[28]	367	Ethiopia	Eastern	48.6	59.3	4.4
Gill *et al* 2008[30]	105	Ethiopia	Eastern	41.0	30.0	51.0
Goro *et al* 2019[31]	208	Ethiopia	Eastern	54.8	47.1	26.0
Hayfron-Benjamin *et al* 2019[70]	206	Ghana	Western	52.9	68.9	32.0
Janmohamed *et al* 2013[32]	369	Tanzania	Eastern	54.0	53.4	83.7
Kahloun *et al* 2014[96]	2320	Tunisia	Northern	–	60.2	3.4
Khalil *et al* 2019[86]	506	Egypt	Northern	–	–	33.2
Lebeta *et al* 2017[38]	344	Ethiopia	Eastern	40.5	42.7	11.4
Machingura *et al* 2017[108]	260	Zimbabwe	Southern	57.6	72.7	45.4
Makwero *et al* 2018[109]	150	Lesotho	Southern	58.2	80.7	6.7
Megallaa *et al* 2019[97]	180	Egypt	Northern	–	24.4	86.1
Mohmad *et al* 2011[81]	71	Sudan	Central	–	42.0	50.7
Molefe-Baikai *et al* 2018[110]	289	Botswana	Southern	50.7	66.1	44.6
Muddu *et al* 2019[46]	175	Uganda	Eastern	46.0	48.6	47.4
Neuhann *et al* 2001[48]	474	Tanzania	Eastern	53.8	46.0	7.5
Olamoyegun *et al* 2015[76]	90	Nigeria	Western	62.5	50.0	54.3
Rotchford *et al* 2002[113]	253	South Africa	Southern	56.5	73.1	46.4
Sobngwi *et al* 2011[3]	2352	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	53.0	61.1	2.4
Tesfaye *et al* 2015[53]	247	Ethiopia	Eastern	–	40.5	6.5

Continued

Table 5 Continued

Prevalence of diabetic nephropathy (n=40 studies): **pooled prevalence=31% (95% CI 22 to 41, I^2=99.3% 95% CI 99.2 to 99.4) and I^2 after meta-regression: 95.6%).**
Prevalence of diabetic nephropathy per region: **Central: 22% (95% CI 9 to 39), Eastern: 25% (95% CI 10 to 43), Southern: 28% (95% CI 18 to 40), Northern: 38% (95% CI 14 to 65) and Western: 47% (95% CI 25 to 69).**

Author and year	No. of study participants	Country (ies)	Region of Africa	Mean age of participants	% of females	Prevalence of nephropathy, %
Thinyane *et al* 2013[114]	80	Lesotho	Southern	49.0	49.0	6.0
Uloko *et al* 2012[67]	531	Nigeria	Western	57.1	60.5	3.2
Worku *et al* 2010[57]	305	Ethiopia	Eastern	44.4	37.1	15.7

supplemental table 2 and online supplemental figures 1–8, respectively.

Based on the NOS, 84 (77.1%) of the included studies were of high quality, with 17 (15.6%) studies and 8 (7.3%) studies being of moderate and low quality, respectively.

Regarding the assessment of publication bias, there was observed publication bias, especially in studies about the prevalence of diabetic nephropathy, peripheral neuropathy and attainment of optimal BP control. The proportion of studies investigating the prevalence of diabetic nephropathy, peripheral neuropathy, peripheral arterial disease, retinopathy and foot ulcers located within the funnel plot was 30% (n=12), 46.1% (n=13), 55.6% (n=10), 57% (29) and 90% (n=26), respectively. About 46%, 65% and 73% of studies that reported the proportion of attainment of optimal BP, HbA1c and LDLC treatment goal were located within the funnel plot, respectively.

Extent of attainment of optimal HbA1c, BP and LDLC goals

Data on the reported proportions achieving the three diabetes treatment goals are summarised in tables 2–4 and as forest plots in figures 2–4.

Data on attainment of optimal HbA1c, BP and LDLC goals were reported in 34 studies,[3 20 21 23 35–37 44–47 59–61 63 64 67 84 87 90 92 93 97–99 104 105 111 116 117 120 124] 26 studies,[3 18 20 21 24 36 40 41 45 47 61 64 67 70 77 87 90 91 96 97 105 107 111 113 120 121] and 11 studies,[21 37 39 47 61 87 90 94 97 111 116] respectively. The pooled proportion of attainment of an optimal HbA1c, BP and LDLC goal in the respective studies was 27% (95% CI 24 to 30, I^2=94.7%), 38% (95% CI 30 to 46, I^2=98.7%) and 42% (95% CI 32 to 52, I^2=97.4%), respectively.

The lowest proportion of attainment of optimal HbA1c was reported in a study performed in Egypt (4.4%)[97] and the highest in a study performed in Nigeria (52.5%).[64] Among studies reporting the extent of attainment of an optimal BP goal, the proportion ranged from 1.5% in a study performed in Uganda[47] to 85.9% in a study performed in Ethiopia.[24] Among the studies reporting information on the optimal LDLC goal, attainment of optimal targets ranged from 20.4% in a study performed in Botswana[111] to 84.8% in a study performed in Sudan.[94]

Regarding the attainment of the diabetes treatment goals in each region of Africa surveyed, the lowest and highest proportion of attainment of an optimal HbA1c goal was noted in the Central (20%, 95% CI 16 to 23) and Western regions (37%, 95% CI 29 to 46), respectively. For the attainment of an optimal BP control, the Western region had the least proportion (31%, 95% CI 20 to 43), while the Northern region had the highest (42%, 95% CI 24 to 61). An optimal LDLC target was least achieved in the Southern region (27%, 95% CI 24 to 30) and most achieved in the Northern region (53%, 95% CI 32 to 74).

Prevalence of diabetic retinopathy, peripheral neuropathy, nephropathy, foot ulcers and peripheral arterial disease

Information on the pooled and specific prevalence of diabetes complications as reported by the different studies is summarised in tables 5–9 and as forest plots in figures 5–9.

The prevalence of diabetic retinopathy, nephropathy, peripheral neuropathy, foot ulcers and peripheral arterial disease was reported in 51 studies,[3 19 24 26 28 30 38 41 48 51 53 54 56–58 65–67 70 72 74 76 77 81 82 86 88 89 91 95–97 102–107 109 112–116 118 120–123 125] 40 studies,[3 19 21 27 28 30–32 38 46 48 53 57 60 62 64 66 67 69 70 76 81 82 86 88 89 91 96 97 100 105 108–110 113 114 117–119 125] 36 studies,[3 19 25 27 28 30 33 34 37 38 43 48 51–53 55 57 58 65 67 68 73 76 79 81 85–88 96 97 105 109 118 125] 29 studies[3 16–19 21 22 25 27 29 38 42 43 48 49 51 53 54 57 58 67 80 85 87 95 97 113 114 125] and 18 studies,[3 20 25 30 43 47 50 52 61 67 70 75 78 85 86 91 97 105] respectively.

Prevalence of diabetic peripheral neuropathy and retinopathy

Diabetic peripheral neuropathy and retinopathy were the most prevalent diabetes complications in the included studies with a pooled prevalence of 38% (95% CI 31 to 45, I^2=98.2%) and 32% (95% CI 28 to 36, I^2=98%), respectively. A wide variation was noted in the prevalence of diabetic peripheral neuropathy across the studies, with prevalence ranging from 4% in a study conducted in Eritrea[51] to 83.3% in a study conducted in Nigeria.[68] A study by Makwero and colleagues[109] conducted in Lesotho reported the lowest prevalence of diabetic retinopathy of 4.7%, while the study by Megalla and colleagues[97] conducted in Egypt reported the highest (90%).

According to the regions of Africa surveyed, the lowest and highest prevalence of diabetic peripheral neuropathy was noted in the Central (22%, 95% CI 18 to 27) and Western regions (61%, 95% CI 45 to 75), respectively. Studies conducted in the Eastern region reported the lowest prevalence of diabetic retinopathy (23%, 95% CI

Table 6 Prevalence of diabetic peripheral neuropathy

Prevalence of diabetic peripheral neuropathy (n=36 studies): **pooled prevalence=38% (95% CI 31 to 45, I^2=98.2% 95% CI 98.7 to 99.0) and I^2 after meta-regression-88%).**
Prevalence of diabetic peripheral neuropathy per region: **Central: 22% (95% CI 18 to 27), Eastern: 26% (95% CI 16 to 38), Northern: 45% (95% CI 30 to 61), Southern: 46% (95% CI 42 to 49) and Western: 61% (95% CI 45 to 75).**

Author and year	No. of study participants	Country(ies)	Region of Africa	Mean age of participants	% of females	Prevalence of neuropathy, %
Abejew *et al* 2015[19]	216	Ethiopia	Eastern	45.0	42.6	14.4
Albalawi *et al* 2020[83]	159	Sudan	Northern	58.1	65.4	40.3
Assaad-Khalil *et al* 2014[85]	958	Egypt	Northern	57.3	50.0	29.3
Awadalla *et al* 2017[87]	424	Sudan	Northern	–	49.3	68.2
Bello *et al* 2019[65]	175	Nigeria	Western	59.8	57.7	41.7
Bentata *et al* 2015[88]	637	Morocco	Northern	58.5	62.3	39.6
Chiwanga *et al* 2015[25]	404	Tanzania	Eastern	53.6	55.4	44.0
Cohen *et al* 2010[105]	620	Malawi	Southern	52.2	60.1	46.4
Deribe *et al* 2014[27]	216	Ethiopia	Eastern	50.7	40.3	10.6
Dzudie *et al* 2012[118]	420	Cameroon	Central	56.7	51.0	22.4
Ede *et al* 2018[68]	90	Nigeria	Western	58.6	34.4	83.3
Ekoru *et al* 2019	2784	Nigeria, Ghana, Kenya	Western and Eastern	56.0	61.0	46.0
Fasil, *et al* 2019[28]	367	Ethiopia	Eastern	48.6	59.3	7.9
Gill *et al* 2008[30]	105	Ethiopia	Eastern	41.0	30.0	41.0
Jarso *et al* 2011[33]	384	Ethiopia	Eastern	–	54.1	77.0
Jember *et al* 2017[34]	368	Ethiopia	Eastern	49.0	41.6	52.2
Kahloun *et al* 2014[96]	2320	Tunisia	Northern	–	60.2	18.7
Khalil *et al* 2019[86]	506	Egypt	Northern	–	–	20.0
Kisozi *et al* 2017[37]	288	Uganda	Eastern	48.5	38.0	29.4
Kuate-Tegueu *et al* 2016[73]	321	Cameroon	Western	59.8	64.1	33.3
Lebeta *et al* 2017[38]	344	Ethiopia	Eastern	40.5	42.7	7.7
Makwero *et al* 2018[109]	150	Lesotho	Southern	58.2	80.7	43.3
Megallaa *et al* 2019[97]	180	Egypt	Northern	–	24.4	82.0
Miriam *et al* 2017[43]	279	Ethiopia	Eastern	48.8	44.8	10.0
Mohmad *et al* 2011[81]	71	Sudan	Central	–	42.0	69.0
Neuhann *et al* 2001[48]	474	Tanzania	Eastern	53.8	46.0	44.0
Olamoyegun *et al* 2015[76]	90	Nigeria	Western	62.5	50.0	69.6
Seyum *et al* 2010[51]	429	Eritrea	Eastern	57.4	–	4.0
Smide *et al* 2009[52]	145	Tanzania	Eastern	46.0	48.0	30.0
Sobngwi *et al* 2011[3]	2352	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	53.0	61.1	48.4
Tesfaye *et al* 2015[53]	247	Ethiopia	Eastern	–	40.5	10.1
Tilahun *et al* 2017[54]	236	Ethiopia	Eastern	47.8	46.6	25.4
Ugoya *et al* 2006[79]	180	Nigeria	Western	53.0	51.6	75.0
Uloko *et al* 2012[67]	531	Nigeria	Western	57.1	60.5	59.2
Vogt *et al* 2017[55]	100	Zanzibar	Eastern	54.0	49.0	45.0
Worku *et al* 2010[57]	305	Ethiopia	Eastern	44.4	37.1	29.5

Table 7 Prevalence of diabetic retinopathy

Prevalence of diabetic retinopathy (n=51 studies): **pooled prevalence=32% (95% CI 28-36, I^2=98% 95% CI 97.8 to 98.3) and I^2 after meta-regression-88.5%).**
Prevalence of diabetic retinopathy per region: **Eastern: 23% (95% CI 19 to 28), Western: 27% (95% CI 19 to 36), Southern: 30% (95% CI 23 to 37), Central: 34% (95% CI 22 to 47) and Northern: 51% (95% CI 37 to 65).**

Author and year	No. of study participants	Country (ies)	Region of Africa	Mean age of participants	% of females	Prevalence of retinopathy, %
Abejew *et al* 2015[19]	216	Ethiopia	Eastern	45.0	42.6	28.9
Ahmed *et al* 2017[82]	316	Sudan	Northern	58.0	41.5	39.8
Albalawi *et al* 2020[83]	159	Sudan	Northern	58.1	65.4	34.6
Assaad-Khalil *et al* 2019[85]	506	Egypt	Northern	–	–	34.6
Awadalla *et al* 2017[87]	424	Sudan	Northern	–	49.3	72.6
Bello *et al* 2019[65]	175	Nigeria	Western	59.8	57.7	33.1
Bello *et al* 2017[66]	358	Nigeria	Western	57.8	61.7	20.1
Bentata *et al* 2015[88]	637	Morocco	Northern	58.5	62.3	35.6
Blake *et al* 2015[102]	1307	Botswana	Southern	55.0	67.9	17.7
Bouaziz *et al* 2012[89]	73	Tunisia	Northern	59.3		27.0
Burgress *et al* 2014[103]	322	Malawi	Southern	55.2	64.6	50.1
Chahbi *et al* 2018[91]	300	Morocco	Northern	–	93.0	34.3
Chisha *et al* 2017[24]	270	Ethiopia	Eastern	–	48.9	13.0
Cleland *et al* 2015[26]	5729	Tanzania	Eastern	60.8	60.3	27.9
Cohen *et al* 2010[105]	620	Malawi	Southern	52.2	60.1	34.7
Dzudie *et al* 2012[118]	420	Cameroon	Central	56.7	51.0	15.7
Ekoru *et al* 2019	2784	Nigeria, Ghana, Kenya	Western and Eastern	56.0	61.0	15.0
Elwali *et al* 2017[95]	316	Sudan	Northern	58.7	40.8	82.6
Fasil *et al* 2019[28]	367	Ethiopia	Eastern	48.6	59.3	17.7
Gill *et al* 2008[30]	105	Ethiopia	Eastern	41.0	30.0	21.0
Glover *et al* 2011[106]	281	Malawi	Southern	56.4	72.8	32.5
Hall *et al* 2017[5 120]	261	Cameroon	Central	56.0	56.3	27.2
Hayfron-Benjamin *et al* 2019[70]	206	Ghana	Western	52.9	68.9	11.0
Jingi *et al* 2014[122]	407	Cameroon	Central	54.2	41.8	38.8
Jingi *et al* 2015[121]	407	Cameroon	Central	–	41.8	40.3
Kahloun *et al* 2014[96]	2320	Tunisia	Northern	–	60.2	26.3
Kizor-Akarairwe *et al* 2018[72]	80	Nigeria	Western	61.2	48.8	32.1
Lartey *et al* 2018[74]	208	Ghana	Western	57.5	70.7	15.5
Lebeta *et al* 2017[38]	344	Ethiopia	Eastern	40.5	42.7	25.5
Lewis *et al* 2018[107]	921	Zambia	Southern	56.0	45.0	44.0
Magan *et al* 2019[41]	44	Uganda	Eastern	50.4	63.4	19.5
Makwero *et al* 2018[109]	150	Lesotho	Southern	58.2	80.7	4.7
Megallaa *et al*, 2019[97]	180	Egypt	Northern	–	24.4	90.0
Mohmad *et al* 2011[81]	71	Sudan	Central	–	42.0	71.2
Neuhann *et al* 2001[48]	474	Tanzania	Eastern	53.8	46.0	14.0
Njikam *et al* 2016[123]	371	Cameroon	Central	59.2	54.7	49.9
Olamoyegun *et al* 2015[76]	90	Nigeria	Western	62.5	50.0	48.9
Onakpoya *et al* 2015[77]	133	Nigeria	Western		48.1	27.8
Pirie *et al* 2014[112]	292	South Africa	Southern	59.2	79.0	39.0

Continued

Table 7 Continued

Prevalence of diabetic retinopathy (n=51 studies): **pooled prevalence=32% (95% CI 28-36, I^2=98% 95% CI 97.8 to 98.3) and I^2 after meta-regression-88.5%).**
Prevalence of diabetic retinopathy per region: **Eastern: 23% (95% CI 19 to 28), Western: 27% (95% CI 19 to 36), Southern: 30% (95% CI 23 to 37), Central: 34% (95% CI 22 to 47) and Northern: 51% (95% CI 37 to 65).**

Author and year	No. of study participants	Country (ies)	Region of Africa	Mean age of participants	% of females	Prevalence of retinopathy, %
Rotchford *et al* 2002[113]	253	South Africa	Southern	56.5	73.1	40.3
Seyum *et al* 2010[51]	429	Eritrea	Eastern	57.4	–	33.0
Sobngwi *et al* 2011[3]	2352	Tanzania, Kenya, Cameroon, Ghana, Senegal, and Nigeria	Eastern, Western, and Central	53.0	61.1	18.3
Tesfaye *et al* 2015[53]	247	Ethiopia	Eastern	–	40.5	11.7
Thinyane *et al* 2013[114]	80	Lesotho	Southern	49.0	49.0	35.0
Thomas *et al* 2013[115]	3978	South Africa	Southern	56.8	33.3	20.5
Tilahun *et al* 2017[54]	236	Ethiopia	Eastern	47.8	46.6	20.3
Uloko *et al* 2012[67]	531	Nigeria	Western	57.1	60.5	35.5
Webb *et al* 2016[116]	599	South Arica	Southern	57.8	68.0	24.9
Woodward *et al* 2020[56]	91	Tanzania	Eastern	59.2	62.6	42.9
Worku *et al* 2010[57]	305	Ethiopia	Eastern	44.4	37.1	33.8

19 to 28) while studies conducted in the Northern region reported the highest prevalence (51%, 95% CI 37 to 65).

Prevalence of diabetic nephropathy, peripheral arterial disease and foot ulcers

The pooled prevalence of diabetic nephropathy, peripheral arterial disease and foot ulcers in the included studies was 31% (95% CI 22 to 41, I^2=99.3%), 19% (95% CI 12 to 25, I^2=98.1%) and 11% (95% CI 9 to 14, I^2=97.4%), respectively.

The prevalence of diabetic nephropathy and peripheral arterial disease ranged from 2.2% in Ethiopia[19] to 90% in Nigeria[64] and 2.7% in a study performed in Morocco[91] to 52.5% in a study performed in Nigeria,[78] respectively. Regarding the burden of diabetic foot ulcers, there was also an observed heterogeneity, with prevalence ranging from 0.4% in Ethiopia[53] to 86.7% in Egypt.[97]

Studies conducted in the Central, Eastern and Southern regions reported a comparable prevalence of diabetic nephropathy (22%, 25% and 28%, respectively) with the highest prevalence reported in studies conducted in the Western region (47%). Regarding the prevalence of PAD, studies conducted in the Southern (8%, 95% CI 6 to 10) and Western (29%, 95% CI 13 to 48) regions reported the lowest and highest prevalence, respectively. A comparable prevalence of diabetic foot ulcers was noted in studies conducted in the Southern, Western and Eastern regions (7%, 8% and 10%, respectively), with the highest prevalence noted in studies conducted in the Northern region (21%).

On sensitivity analysis considering only high-quality studies, the pooled prevalence of the five diabetic complications and the proportion of attainment of the three optimal diabetes treatment goals did not differ from those obtained in the preliminary analysis with all eligible studies included. The pooled prevalence of diabetic foot ulcers, peripheral arterial disease, diabetic nephropathy, diabetic retinopathy and diabetic peripheral neuropathy after sensitivity analysis was 9% (95% CI 7 to 12, I^2=92.9%), 20% (95% CI 13 to 28, I^2=98.4%), 31% (95% CI 21 to 42, I^2=99.4%), 33% (95% CI 28 to 37, I^2=98.2%) and 40% (95% CI 32 to 48, I^2=99%), respectively. The pooled proportion of attainment of optimal HbA1c, BP and LDLC treatment goal was 27% (95% CI 23 to 30, I^2=94.5%), 37% (95% CI 29 to 46, I^2=99.0%) and 43% (95% CI 31 to 55, I^2=97.9%), respectively.

DISCUSSION

To our knowledge, this is the first systematic review and meta-analysis to simultaneously document the proportion of attainment of the three key indicators of optimal diabetes care (HbA1c, BP, and LDLC goals) and the burden of five diabetes complications in an indigenous adult population with type 2 diabetes in Africa. In this study of a total of 63 890 study participants, we report that, generally, a small proportion of adult patients with type 2 diabetes in Africa attain optimal diabetes treatment targets, especially HbA1c and BP goals (less than 40%). In addition, diabetes complications are relatively common with diabetic neuropathy being the most prevalent (38%) followed by diabetic retinopathy (32%), nephropathy (31%), peripheral arterial disease (19%) and foot ulcers (11%).

Table 8 Prevalence of diabetic foot ulcers

Prevalence of diabetic foot ulcers (n=29 studies): **pooled prevalence=11% (95% CI 9 to 14, I^2=97.4% 95% CI 96.9 to 97.8), and I^2 after meta-regression :1.4%).**
Prevalence of diabetic foot ulcers per region: **Southern: 7% (95% CI 5 to 11), Western: 8% (95% CI 6 to 10), Eastern: 10% (95% CI 8 to 12) and Northern: 21% (95% CI 4 to 48).**

Author and year	No. of study participants	Country(ies)	Region of Africa	Mean age of participants	% of females	Prevalence of foot ulcers, %
Abbas *et al* 2002[16]	627	Tanzania	Eastern	53.0	35.0	15.0
Abbas *et al* 2011[17]	11 866	Tanzania	Eastern	–	–	12.0
Abdissa *et al* 2020[18]	229	Ethiopia	Eastern	–	40.4	12.7
Abejew *et al* 2015[19]	216	Ethiopia	Eastern	45.0	42.6	4.4
Albalawi *et al* 2020[83]	159	Sudan	Northern	58.1	65.4	2.5
Amour *et al* 2019[21]	315	Tanzania	Eastern	57.2	65.7	10.0
Assaad-Khalil *et al* 2014[85]	958	Egypt	Northern	57.3	50.0	6.1
Awadalla *et al* 2017[87]	424	Sudan	Northern	–	49.3	12.7
Chalya *et al* 2011 105[22]	136	Tanzania	Eastern	54.3	45.6	3.2
Chiwanga *et al* 2015[25]	404	Tanzania	Eastern	53.6	55.4	15.0
Deribe *et al* 2014[27]	216	Ethiopia	Eastern	50.7	40.3	14.8
Ekoru K *et al* 2019	2784	Nigeria, Ghana, Kenya	Western and Eastern	56.0	61.0	5.0
Elwali *et al* 2017[95]	316	Sudan	Northern	58.7	40.8	17.7
Gebrekirstos *et al* 2015[29]	228	Ethiopia	Eastern	–	38.0	12.0
Lebeta *et al* 2017[38]	344	Ethiopia	Eastern	40.5	42.7	21.2
Mamo *et al* 2015[42]	200	Ethiopia	Eastern	50.0	72.5	15.0
Mariam *et al* 2017[43]	279	Ethiopia	Eastern	48.8	44.8	13.6
Megallaa *et al* 2019[97]	180	Egypt	Northern	–	24.4	86.7
Neuhann *et al* 2001[48]	474	Tanzania	Eastern	53.8	46.0	10.0
Nyamu *et al* 2003[49]	1788	Kenya	Eastern	56.9	–	4.6
Rotchford *et al* 2002[113]	253	South Africa	Southern	56.5	73.1	6.0
Seyum *et al* 2010[51]	429	Eritrea	Eastern	57.4	–	14.0
Sobngwi *et al* 2011[3]	2352	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	53.0	61.1	11.7
Tesfaye *et al* 2015[53]	247	Ethiopia	Eastern	–	40.5	0.4
Thinyane *et al* 2013[114]	80	Lesotho	Southern	49.0	49.0	14.0
Tilahun *et al* 2017[54]	236	Ethiopia	Eastern	47.8	46.6	8.5
Uloko *et al* 2012[67]	531	Nigeria	Western	57.1	60.5	3.8
Unachukwu *et al* 2006[80]	315	Nigeria	Western	54.6	36.7	19.1
Worku *et al* 2010[57]	305	Ethiopia	Eastern	44.4	37.1	4.6

Proportions of attainment of the optimal diabetes treatment goals

A wide heterogeneity in the attainment of the optimal diabetes treatment goals was noted across all five regions of Africa. This could probably be explained by the marked differences in the populations studied, healthcare systems and knowledge-practice gaps among healthcare practitioners.

Similar to our study findings, achievement of optimal HbA1c, BP and LDLC treatment goals has also been widely reported to be a significant clinical challenge in several studies performed in Caucasian and Asian populations with type 2 diabetes in high-income and middle-income countries.[126–131] In one large registry-based study of >100 000 adults with a self-reported diagnosis of diabetes carried out between 1999 and 2010 in USA,

Table 9 Prevalence of peripheral arterial disease

Prevalence of peripheral arterial disease (PAD) (n=18 studies): **Pooled prevalence=19% (95% CI 12 to 25, I^2=98.1% 95% CI 97.6 to 98.4) and I^2 after meta-regression: 70.9%).** Prevalence of PAD per region: **Southern: 8% (95% CI 6 to 10), Northern: 15% (95% CI 4 to 29), Eastern: 18% (95% CI 11 to 27) and Western: 29% (95% CI 13 to 48).**						
Author and year	**No. of study participants**	**Country(ies)**	**Region of Africa**	**Mean age of participants**	**% of females**	**Prevalence of PAD, %**
Agboghoroma *et al* 2020[61]	200	Nigeria	Western	–	–	38.5
Akalu *et al* 2020[20]	280	Ethiopia	Eastern	–	38.6	30.7
Assaad-Khalil *et al* 2014[85]	958	Egypt	Northern	57.3	50.0	11.0
Chahbi *et al* 2018[91]	300	Morocco	Northern	–	93.0	2.7
Chiwanga *et al* 2015[25]	404	Tanzania	Eastern	53.6	55.4	15.0
Cohen *et al* 2010[105]	620	Malawi	Southern	52.2	60.1	7.6
Gill *et al* 2008[30]	105	Ethiopia	Eastern	41.0	30.0	6.0
Hayfron-Benjamin *et al* 2019[70]	206	Ghana	Western	52.9	68.9	11.2
Khalil *et al* 2019[86]	506	Egypt	Northern	–	–	32.6
Mariam *et al* 2017[43]	279	Ethiopia	Eastern	48.8	44.8	9.7
Megallaa *et al* 2019[97]	180	Egypt	Northern	–	24.4	20.0
Mwebaze *et al* 2014[47]	146	Uganda	Eastern	53.9	48.6	39.0
Ogbera *et al* 2015[75]	225	Nigeria	Western	61.4	57.0	40.0
Okello *et al* 2014[50]	229	Uganda	Eastern	60.0	63.7	24.0
Oyelade *et al* 2012[78]	219	Nigeria	Western	–	58.9	52.5
Smide *et al* 2008[52]	145	Tanzania	Eastern	46.0	48.0	13.0
Sobngwi *et al* 2011[3]	2352	Tanzania, Kenya, Cameroon, Ghana, Senegal and Nigeria	Eastern, Western and Central	53.0	61.1	4.7
Uloko *et al* 2012[67]	531	Nigeria	Western	57.1	60.5	10.7

33.4%–48.7% of adult patients with diabetes did not achieve the recommended HbA1c, BP and LDLC treatment targets. Less than 15% met all the three treatment targets in addition to smoking cessation.[126]

Similarly, a low proportion of achievement of an optimal HbA1c target was also reported by a large international, multicentre observational study of 2704 multiracial adult populations with diabetes from 10 countries (two from Africa, five from the Middle East and three from South Asia). About 46% of the participants were Caucasian. An optimal HbA1c goal of <7% (53 mmol/mol) was reported in only 25.8% of the participants.[128]

In the Japan Epidemiology Collaboration on Occupational Health study, which enrolled 3070 adult employees of large manufacturing companies, optimal HbA1c, BP and LDLC goals as recommended by the ADA were noted in 44.9%, 76.6% and 27.1% of participants, respectively. Only 11.2% of participants attained all three treatment goals.[129]

The burden of diabetes complications in Africa

Regarding studies on the burden of diabetes complications in Africa, there were few that investigated the prevalence of diabetic foot ulcers and peripheral arterial disease with diabetic retinopathy, peripheral nephropathy and neuropathy being the most studied. Diabetic peripheral neuropathy and retinopathy remain the most prevalent diabetes complication and diabetic foot ulcers the least prevalent.

With regards to the prevalence of diabetic foot ulcers, an earlier published systematic review and meta-analysis on the characteristics, prevalence and outcomes of diabetic foot ulcers in Africa by Rigato *et al*[132] reported a pooled prevalence of diabetic foot ulcers of 13%, a finding close to what we observed (11%). In another systematic review and meta-analysis on the prevalence of diabetic peripheral neuropathy in African populations with DM, Shiferaw *et al*[133] reported a slightly higher overall prevalence of 46% compared with what we found in our study (38%) while including fewer studies (n=23).

Similar to our study, considerable heterogeneity was also reported in the documented prevalence of the varied diabetes complications in Africa in most previously published systematic reviews. This may be due to variations in clinical definitions of diabetes complications in the studies. Burgess *et al*[134] and Achigbu *et al*[135] reported a wide disparity in the prevalence of diabetic retinopathy

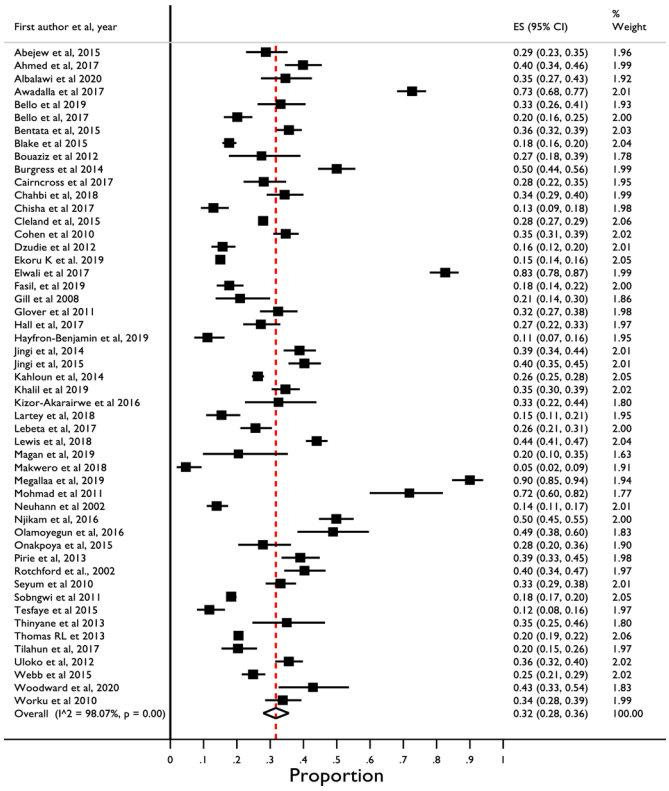

Figure 5 Forest plot summarising studies on the prevalence of diabetic retinopathy. ES, effect size.

in the included studies of 7%–62.4%, and 13%–82.6%, respectively. Noubiap *et al*[136] in a systematic review on the burden of diabetic nephropathy in 2015 reported an overall prevalence of chronic kidney disease in patients with diabetes ranging between 11% and 83.7%. Johnston *et al* in a systematic review that aimed to assess the

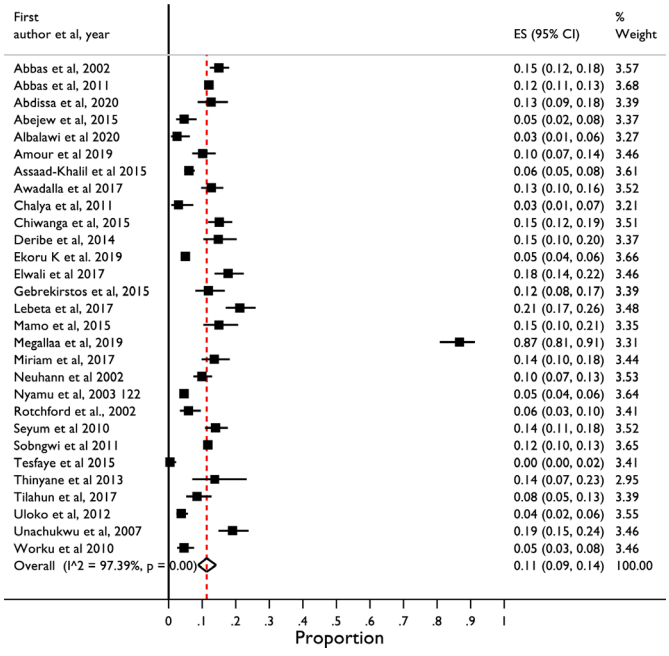

Figure 6 Forest plot summarising studies on the prevalence of diabetic foot ulcers. ES, effect size.

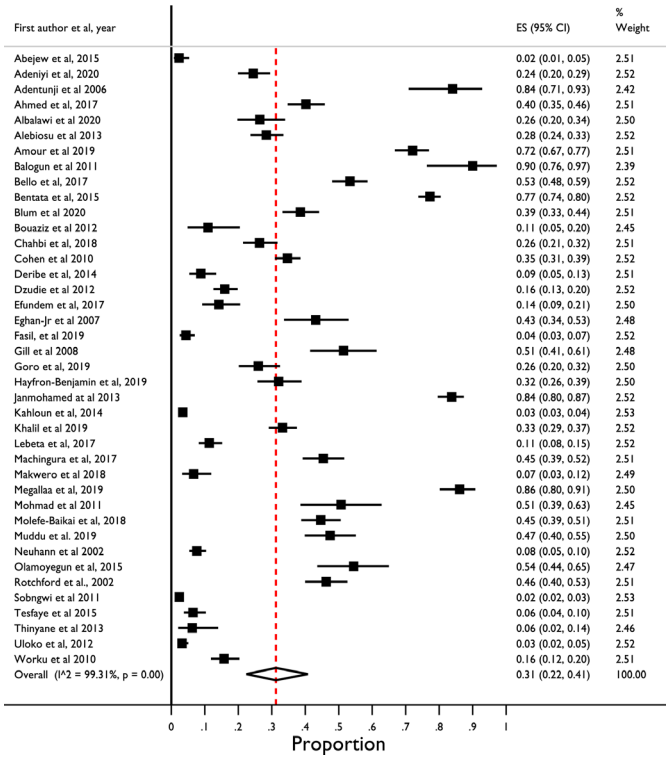

Figure 7 Forest plot summarising studies on the prevalence of diabetic nephropathy. ES, effect size.

epidemiological and clinical reports regarding Peripheral arterial disease (PAD) in Sub-saharan Africa (SSA) documented the prevalence of PAD in patients with diabetes as reported by three studies to range from 39% to 52%.[137]

Compared with Caucasian and Asian adult populations with type 2 diabetes, our study has demonstrated that

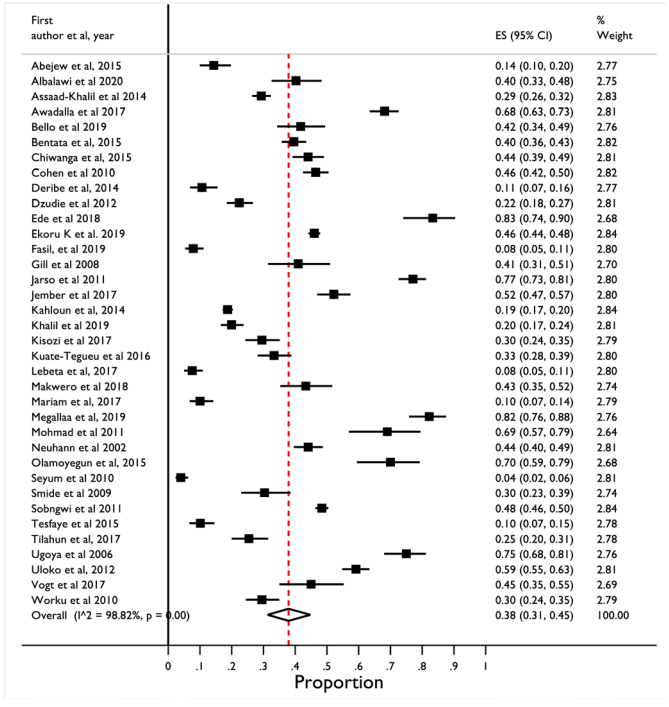

Figure 8 Forest plot summarising studies on the prevalence of diabetic neuropathy. ES, effect size.

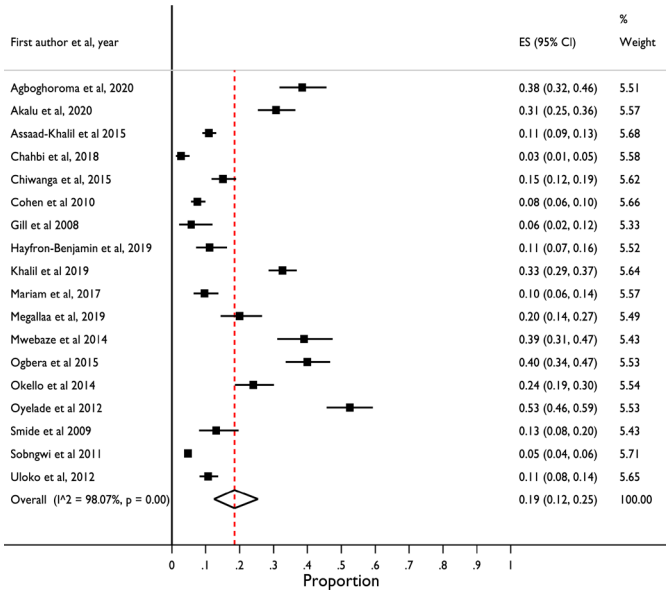

Figure 9 Forest plot summarising studies on the prevalence of peripheral arterial disease. ES, effect size.

adult African patients are disproportionately affected by complications of DM. The Joint Asia Diabetes Evaluation programme that undertook comprehensive risk assessments of 3687 adult patients with type 2DM recruited from seven Asian countries reported a prevalence of peripheral arterial disease, diabetic neuropathy, macroalbuminuria and microalbuminuria and diabetic retinopathy of 3.1%, 15%, 18.8% and 20.4%, respectively.[138]

The National Health and Nutrition Examination Survey conducted from 1988 to 1994 and 1999–2018 in USA in 1486 non-pregnant adults (aged ≥20 years) with newly diagnosed diabetes (diagnosed within the past 2 years) also documented a low burden of most diabetes complications. Diabetic foot ulcers, peripheral arterial disease, diabetic retinopathy, neuropathy and nephropathy (albuminuria) were prevalent in 6.3%, 9.2%, 12.1%, 14.5% and 18.7%, respectively.[139]

The documented low proportions of attainment of optimal diabetes treatment goals (optimal HbA1c, BP and LDLC targets) in Africa is associated with an increased risk of onset and progression of diabetes complications, hence increasing morbidity and mortality in addition to causing a significant economic strain on the meagre health resources. This generally observed low proportion of attainment of key diabetes treatment goals and high prevalence of diabetes complications, notably diabetic neuropathy, retinopathy and nephropathy in Africa, exists broadly due to challenges related to screening, diagnosis and management of DM.

Awareness of diabetes in the general African population and healthcare practitioners remains very poor, resulting in delayed diagnosis of diabetes. The challenge of ready access to affordable essential diabetes medicines like insulin and statins and diagnostic tests or equipment like glucometers for home self-monitoring of glucose, HbA1c and lipid profile tests remains highly prevalent in most African countries.[140–144]

Effective management of diabetes and its related cardiovascular risk factors like hypertension and dyslipidaemia in most healthcare settings in Africa also remains a significant clinical challenge.[3] Most healthcare facilities especially the lower tier ones lack local or institution-specific comprehensive diabetes treatment guidelines to guide healthcare practitioners on how to optimally manage diabetes, in addition to the evident knowledge–practice gaps among healthcare practitioners.[2]

Healthcare systems in most African countries remain poorly structured to optimally manage most NCDs like diabetes along with an inadequately funded health sector. Most African countries have not yet fulfilled the 2001 Abuja Declaration of allocating 15% of their national annual budget to the health sector.[2 145]

This systematic review and meta-analysis had its strengths and limitations. To our knowledge, it is the first to simultaneously investigate the status of attainment of the three key diabetes treatment goals and the burden of five common diabetes complications in an adult indigenous African population with type 2 diabetes. The systematic review and meta-analysis included a large number of studies that assessed the extent of attainment of diabetes treatment goals and the prevalence of diabetes complications based on recommendations or definitions by internationally recognised associations.

It also had its limitations. There was considerable heterogeneity in the included studies. This could be explained by the differences in study sites (tertiary vs low-tier hospitals or private vs public hospitals), patient characteristics (age, duration of diabetes, coexisting medical conditions), regions where the studies were conducted and diagnostic modalities used to identify diabetes complications. The systematic review also excluded studies published in French, which is the official language of some African countries. However, these were very few. There was evidence of publication bias in some of the included studies especially studies investigating the prevalence of diabetic nephropathy and peripheral neuropathy and the proportion of attainment of an optimal BP goal. About 23% of the included studies were moderate and low quality on assessment using the NOS for cross-sectional studies.

CONCLUSION

Achievement of optimal diabetes treatment goals, especially HbA1c and BP, in adult African patients with type 2 diabetes remains low in Africa. Diabetes complications especially diabetic peripheral neuropathy and retinopathy also remain highly prevalent. Implementation of universal diabetes screening and education initiatives coupled with improving knowledge about diabetes management among healthcare practitioners and ready access to affordable essential diabetes diagnostic tests and medicines in Africa are integral in improving

overall optimal diabetes care and reducing the burden of diabetes complications.

Considering the projected future increase in the prevalence of diabetes globally, especially in the African region, there is an urgent need to address glaring gaps in diabetes care and to develop simple and pragmatic interventions to improve treatment outcomes and reduce the burden of diabetes complications.

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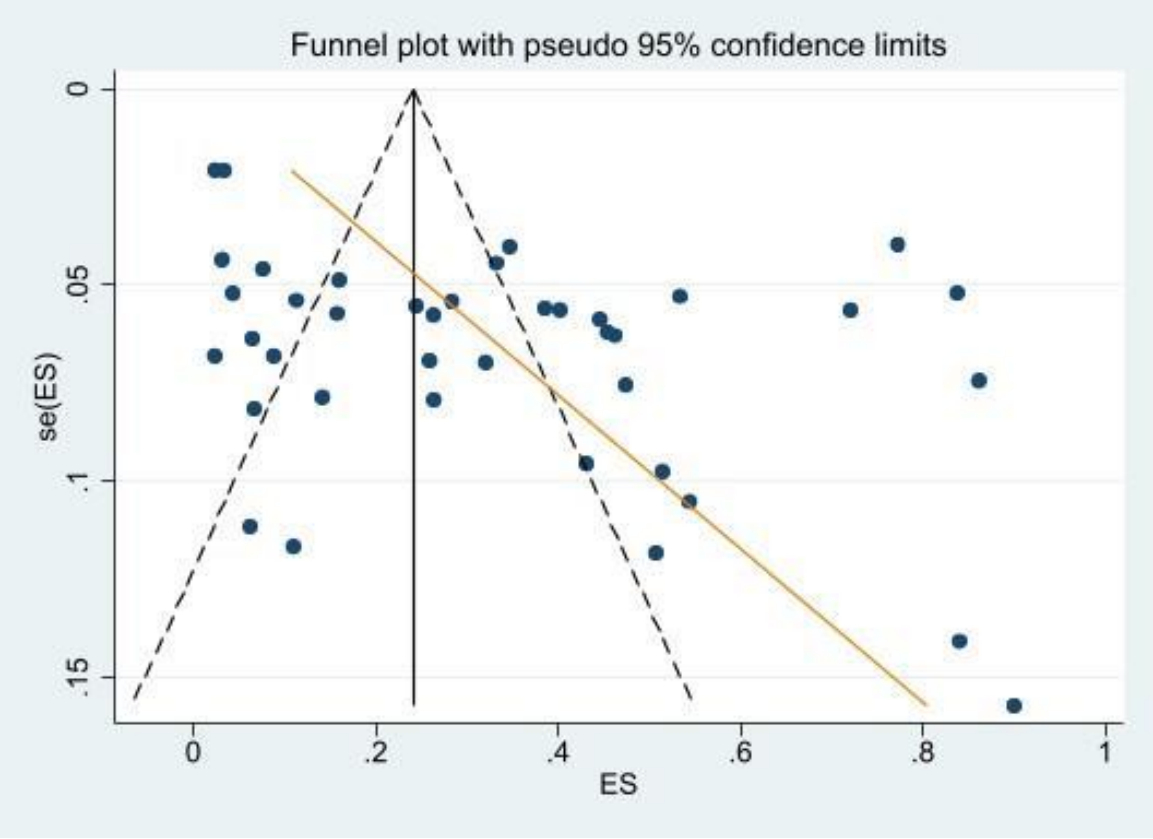
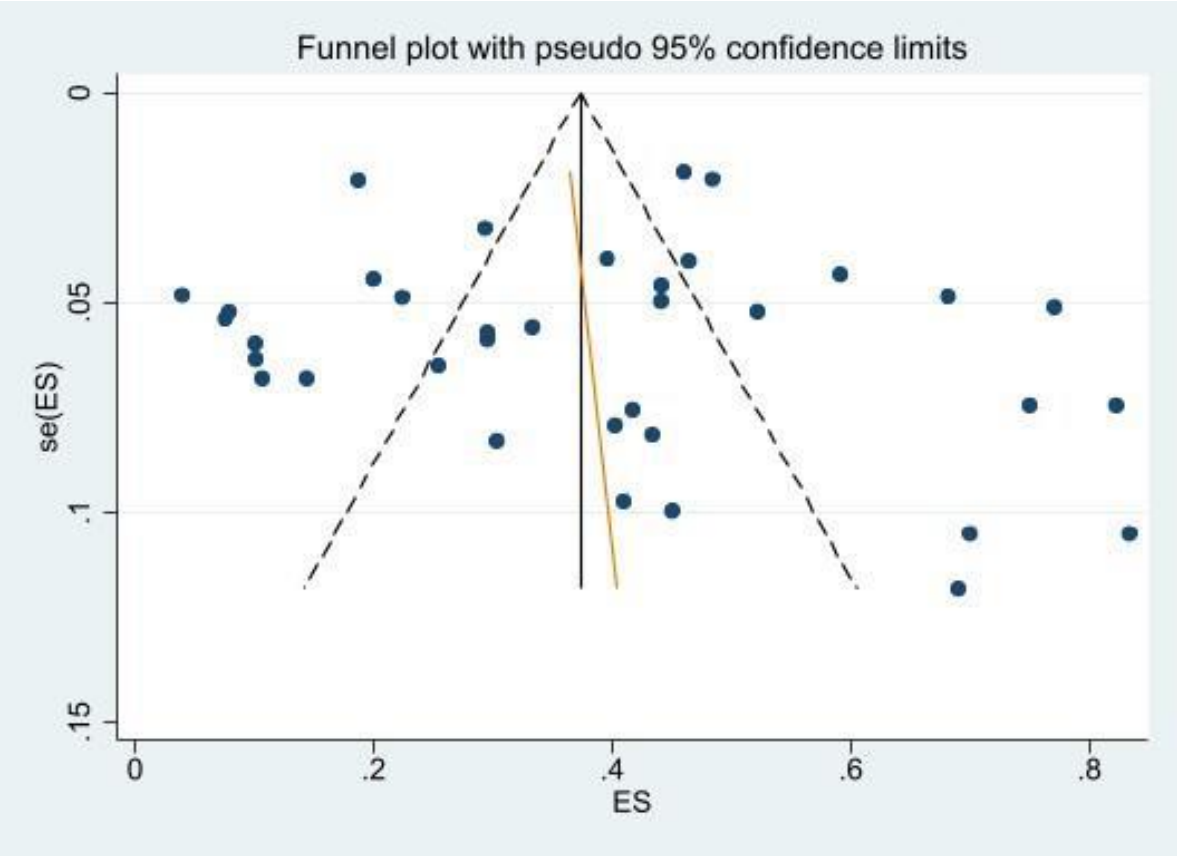
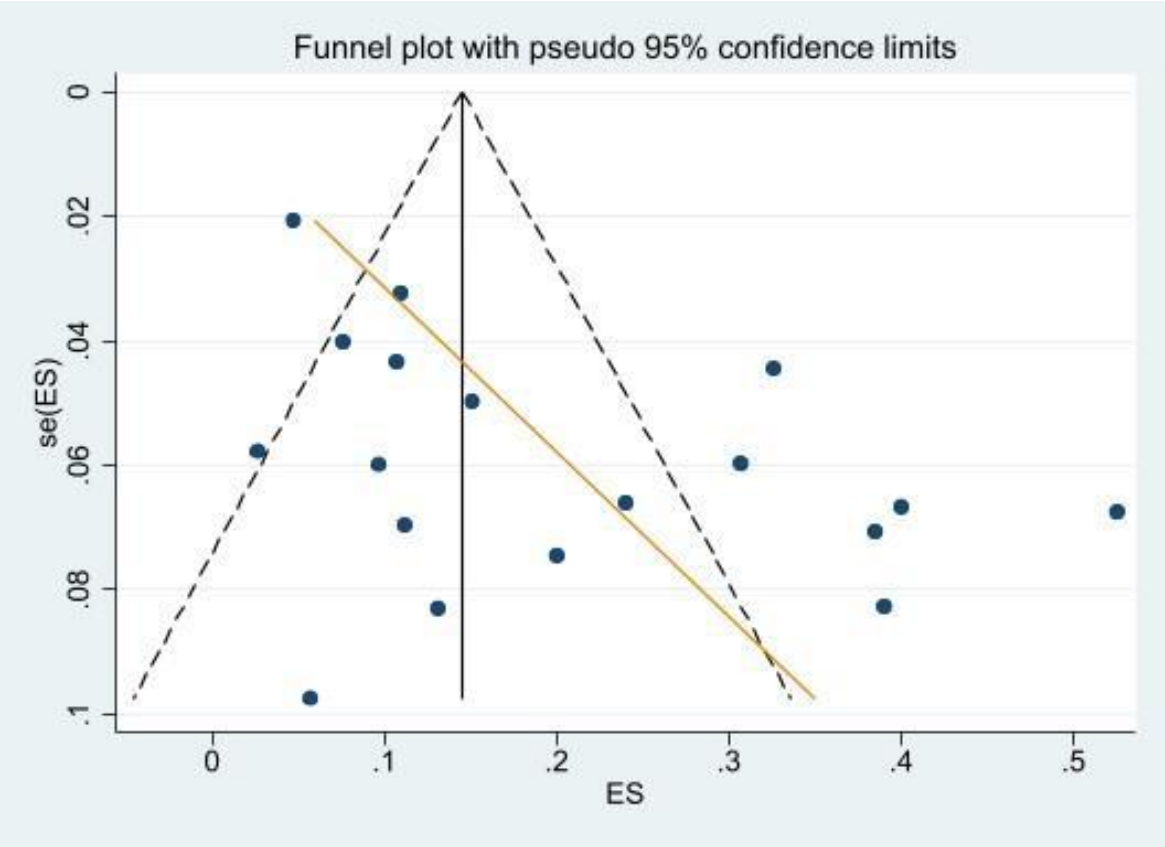
Supplementary figure 1: Funnel plot for studies investigating the prevalence of diabetic nephropathy



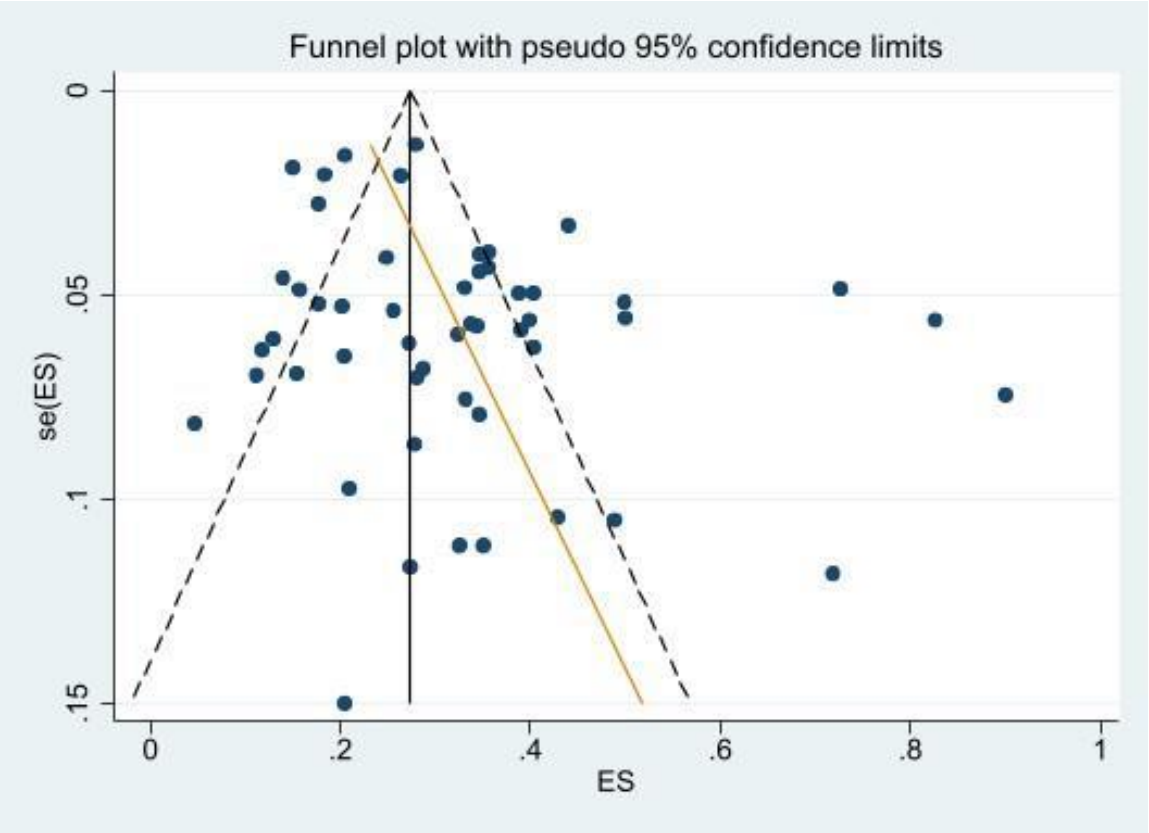
Supplementary figure 2: Funnel plot for studies investigating the prevalence of diabetic neuropathy



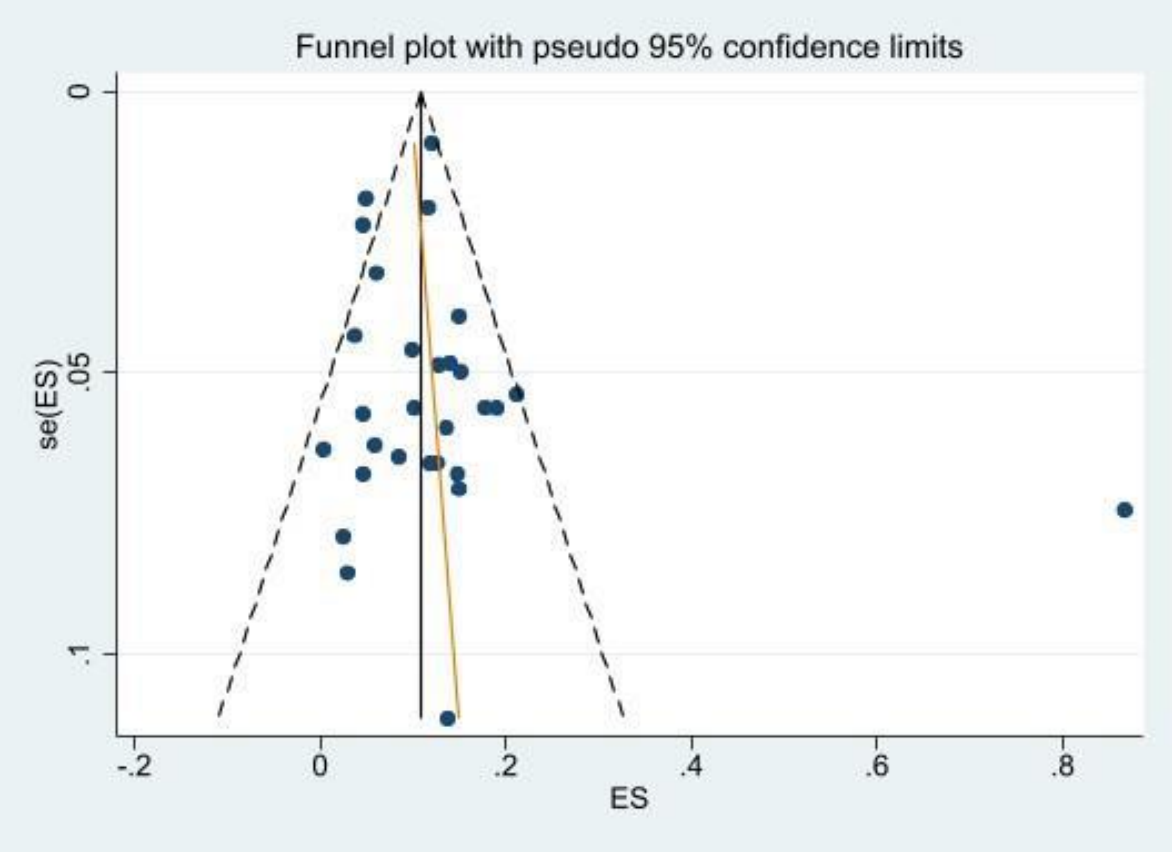
Supplementary figure 3: Funnel plot for studies investigating the prevalence of peripheral arterial disease



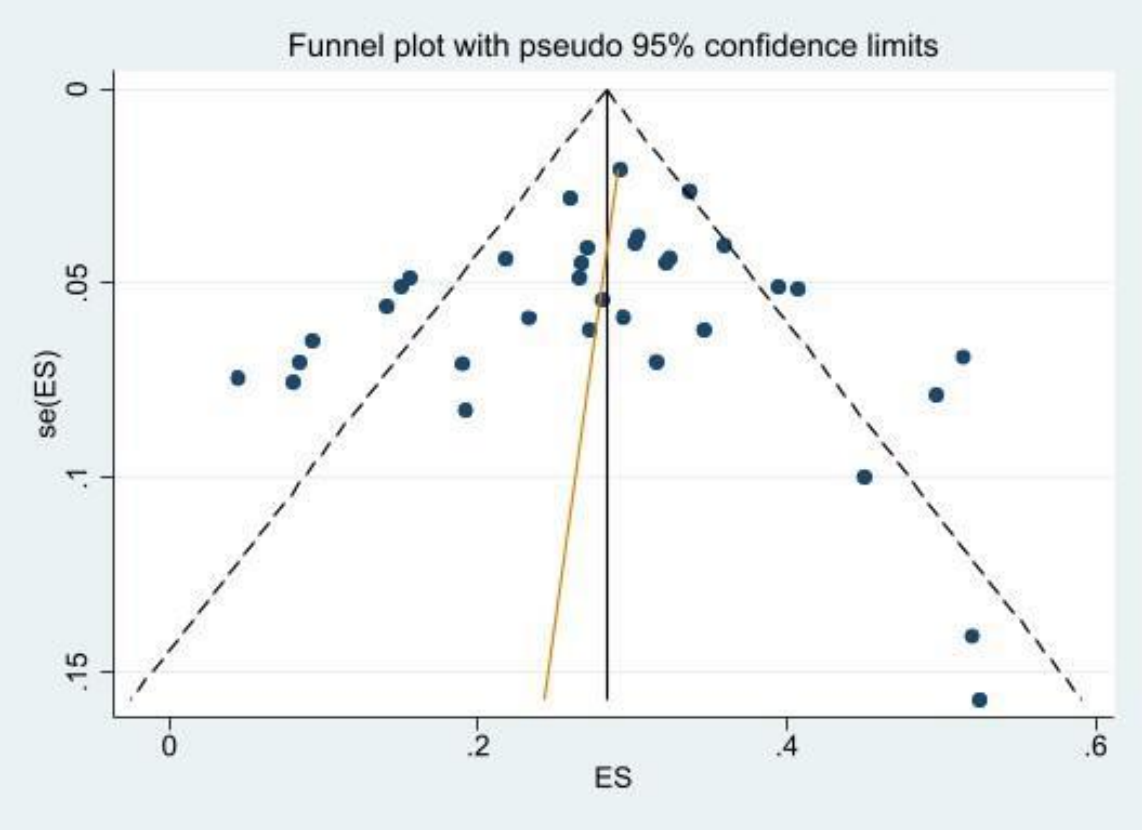
Supplementary figure 4: Funnel plot for studies investigating the prevalence of diabetic retinopathy



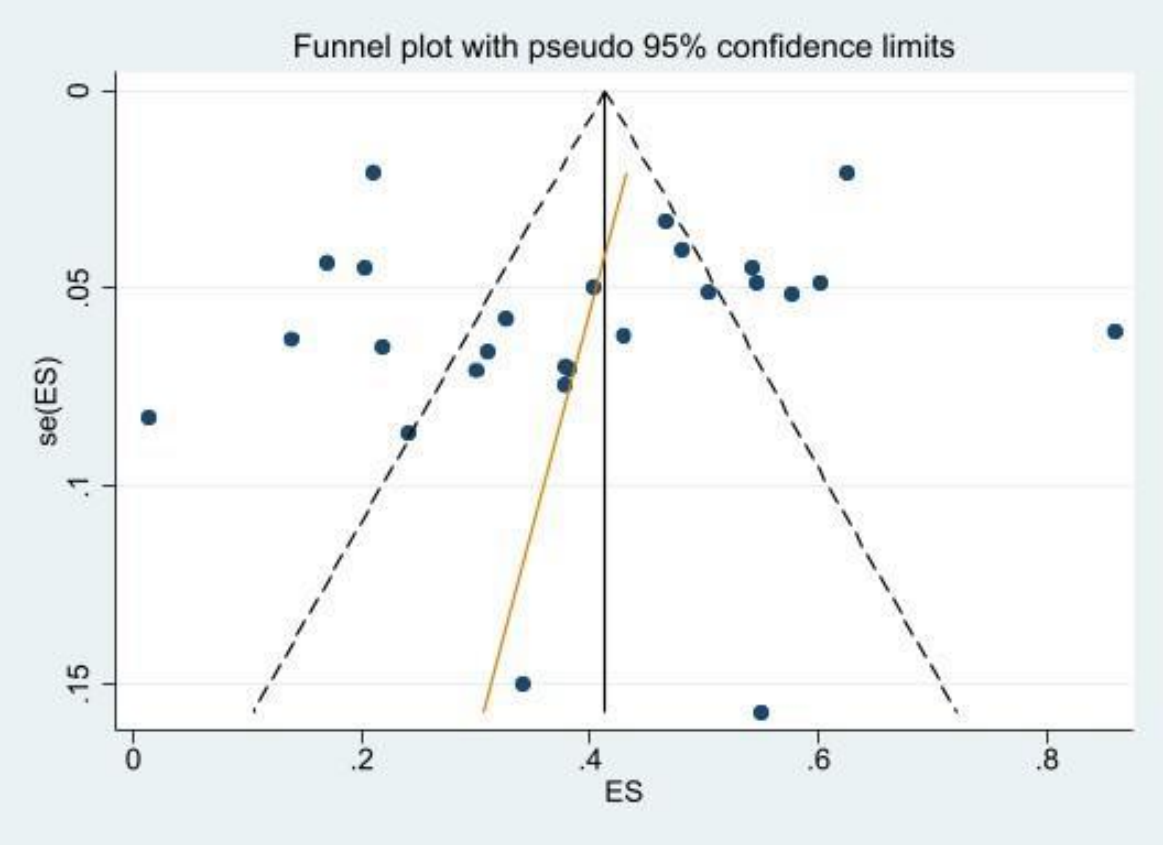
Supplementary figure 5: Funnel plot for studies investigating the prevalence of diabetic foot ulcers



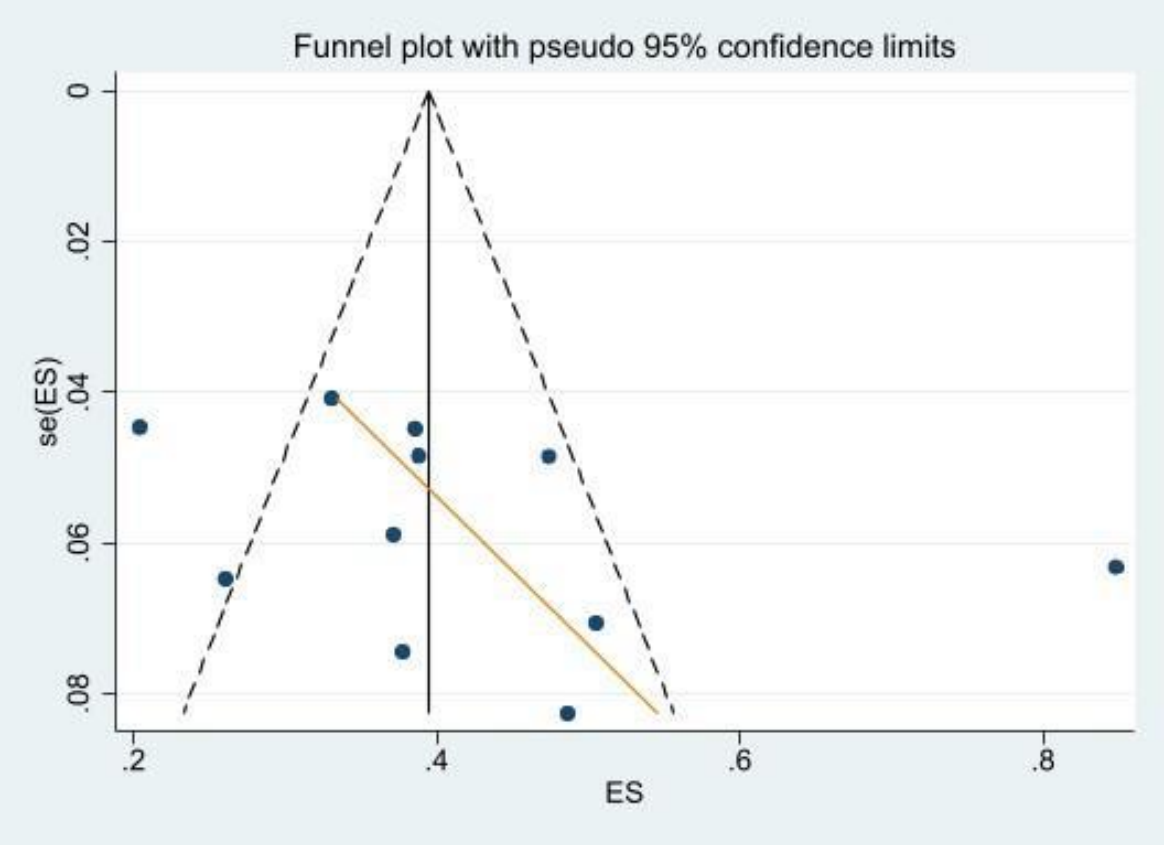
Supplementary figure 6: Funnel plot for studies investigating the rate of attainment of an optimal HbA1c goal



Supplementary figure 7: Funnel plot for studies investigating the rate of attainment of an optimal BP goal



Supplementary figure 8: Funnel plot for studies investigating the rate of attainment of an optimal LDLC goal



Supplementary table 1. PRISMA checklist for the systematic review and meta-analysis

Section and Topic	Item #	Checklist item	Page where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	5-6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	6
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	8
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	6
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	6-7
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	7-8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	9-10
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	9-10
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	10
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	10
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	10-11

Section and Topic	Item #	Checklist item	Page where item is reported
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	10-11
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	10
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	10-11
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	10-11
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	11
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	11
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	11
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	11-12
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	12
Study characteristics	17	Cite each included study and present its characteristics.	12
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	13-14
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	14-17
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	13-14
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	14-17
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	12
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	17
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	13
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	13
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	17-21
	23b	Discuss any limitations of the evidence included in the review.	21

Section and Topic	Item #	Checklist item	Page where item is reported
	23c	Discuss any limitations of the review processes used.	21
	23d	Discuss implications of the results for practice, policy, and future research.	22
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	6
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	A protocol was not prepared
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Search period was changed from September 2020 to December 2020
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	22-23
Competing interests	26	Declare any competing interests of review authors.	23
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	23

Supplementary table 2. Criteria for the adapted Newcastle-Ottawa Scale regarding star allocation to assess quality of included studies

	Selection				Comparability	Outcome		
Study details (Author et al, year)	**Representativeness of sample (⋆)**	**Sample size (⋆)**	**Non respondents (⋆)**	**Ascertainment of exposure (*)**	**(⋆⋆)**	**Assessment of outcome (⋆)**	**Statistical test (⋆)**	**Total (8*)**
Mariam et al, 2017	*	*	*	*	**	*	*	8
Okello et al, 2014	*	*	*	*	**	*	*	8
Amour et al, 2019	*	*	*	*	**	*	*	8
Abdissa et al, 2019	*	*	*	*	**	*	*	8
Fasil et al, 2019	*	*	*	*	**	*	*	8
Jember et al,2017	*	*	*	*	**	*	*	8
Chisha et al, 2017	*	*	*	*	**	*	*	8
Deribe et al, 2014	*	*	*	*	**	*	*	8
Seyum et al, 2008	*	*	*	*	**	*	*	8
Muddu et al,2019	*	*	*	*	**	*	*	8
Mamo et al., 2015	*	*	*	*	**	*	*	8
Muddu et al., 2019	*	*	*	*	**	*	*	8
Blake et al., 2015	*	*	*	*	**	*	*	8
Bello et al., 2019	*	*	*	*	**	*	*	8
Elnasri et al., 2008	*	*	*	*	**	*	*	8
Iwuala et al., 2015	*	*	*	*	**	*	*	8
Chadli et al., 2016	*	*	*	*	**	*	*	8
Jingi et al., 2014	*	*	*	*	**	*	*	8
Hall et al., 2017	*	*	*	*	**	*	*	8
Efundem et al., 2017	*	*	*	*	**	*	*	8
Attoye et al., 2020	*	*	*	*	**	*	*	8
Chetoui et al., 2020	*	*	*	*	**	*	*	8
Diaf et al., 2017	*	*	*	*	**	*	*	8
Elwali et al., 2017	*	*	*	*	**	*	*	8
Kahloun et al., 2014	*	*	*	*	**	*	*	8
Noor et al., 2017	*	*	*	*	**	*	*	8
Bello et al., 2017	*	*	*	*	**	*	*	8
Uloko et al., 2012	*	*	*	*	**	*	*	8
Ede et al., 2018	*	*	*	*	**	*	*	8

Hayfron-Benjamin et al., 2019	*	*	*	*	**	*	*	8
Kizor-Akaraiwe et al., 2016	*	*	*	*	**	*	*	8
Ogbera et al., 2015	*	*	*	*	**	*	*	8
Olamoyegun et al., 2015	*	*	*	*	**	*	*	8
Oyelade et al., 2012	*	*	*	*	**	*	*	8
Ugoya et al., 2006	*	*	*	*	**	*	*	8
Ahmed et al., 2017	*	*	*	*	**	*	*	8
Albalawi et al., 2020	*	*	*	*	**	*	*	8
Ashur et al., 2016	*	*	*	*	**	*	*	8
Blum et al., 2020	*	*	*	*	**	*	*	8
Burgess et al., 2014	*	*	*	*	**	*	*	8
Glover et al., 2012	*	*	*	*	**	*	*	8
Lewis et al., 2018	*	*	*	*	**	*	*	8
Machingura et al., 2017	*	*	*	*	**	*	*	8
Molefe-Baikai et al., 2018	*	*	*	*	**	*	*	8
Mwita et al., 2019	*	*	*	*	**	*	*	8
Pirie et al., 2014	*	*	*	*	**	*	*	8
Rotchford et al., 2002	*	*	*	*	**	*	*	8
Thomas et al., 2013	*	*	*	*	**	*	*	8
Webb et al., 2015	*	*	*	*	**	*	*	8
Omar et al., 2018	*	*	*	*	**	*	*	8
Adeniyi et al., 2020	*	*	*	*	**	*	*	8
Assaad-Khalil et al., 2015	*	*	*	*	**	*	*	8
Khalil et al., 2019	*	*	*	*	**	*	*	8
Awadalla et al., 2017	*	*	*	*	**	*	*	8
Bentata et al., 2015	*	*	*	*	**	*	*	8
Bouaziz et al., 2012	*	*	*	*	**	*	*	8
Jingi et al., 2015	*	*	*	*	**	*	*	8

Chahbi et al., 2018	*	*	*	*	**	*	*	8
Adetunji et al., 2006	*	*	*	*	**	*	*	8
Jarso et al., 2011	*	*	*	*	**	*	*	8
Janmohamed et al, 2013	*	*	*	*	*	*	*	7
Chalya et al, 2011	*	*	*	*	*	*	*	7
Goro et al, 2019	*	*	*	*	*	*	*	7
Muddu et al, 2016	*	*	-	*	**	*	*	7
Kisozi et al, 2017	*	*	*	*	*	*	*	7
Akalu et al, 2020	*	*	*	*	*	*	*	7
Lumu et al, 2017	*	*	*	*	*	*	*	7
Chamba et al, 2017	*	*	-	*	**	*	*	7
Smide et al, 2008	*	-	*	*	**	*	*	7
Sobngwi et al 2011	*	-	*	*	**	*	*	7
Camara et al, 2014	*	-	*	*	**	*	*	7
Ekoru et al,2019	*	-	*	*	**	*	*	7
Mwebaze et al, 2014	*	*	*	*	*	*	*	7
Agboghoroma et al,2020	*	*	*	*	*	*	*	7
Kimando et al, 2017	*	*	-	*	**	*	*	7
Clealand et al, 2015	*	*	*	*	*	*	*	7
Njikam et al., 2016	*	*	-	*	**	*	*	7
Dzudie et al., 2012	*	*	*	-	**	*	-	7
Alebiosu et al., 2003	*	*	-	*	**	*	*	7
Kuate-Tegueu et al., 2015	*	*	-	*	**	*	*	7
Mohmad et al., 2011	*	*	-	*	**	*	*	7
Cohen et al., 2010	*	*	-	*	**	*	*	7
Makwero et al., 2018	*	*	-	*	**	*	*	7
Onakpoya et al., 2016	*	-	-	*	**	*	*	7
Lebeta et al, 2016	*	*	*	*	-	*	*	6
Kibirige et al, 2017	*	-	-	*	**	*	*	6
Mbwete et al, 2020	*	-	*	*	*	*	*	6
Tiahun et al,2017	*	*	*	*	-	*	*	6

Chiwanga et al, 2015	*	-	*	*	*	*	*	6
Lumu et al, 2017	*	-		*	**	*	*	6
Balogu et al., 2011	*	-	-	*	**	*	*	6
Megallaa et al., 2019	*	*	*	*	-	*	*	6
Eghan et al., 2007	*	*	-	-	**	*	*	6
Unachukwu et al., 2007	*	-	-	*	**	*	*	6
Abejew et al, 2015	*	*	-	*	-	*	*	5
Nyamu et al, 2003	*	-	*	*	-	*	*	5
Gulam-Abbas et al, 2002	*	-	*	*	-	*	*	5
Abbas et al, 2011	*	*	*	*	-	*	-	5
Gill et al, 2008	*	*	*	*	-	*	-	5
Cairncross et al., 2017	-	-	-	*	**	*	*	5
Amod et al., 2012	*	*	*	-	-	*	*	5
Vogt et al, 2017	*	-	-	*	-	*	*	4
Worku et al, 2010	*	*	*	-	-	*	-	4
Gebrekirstos et al, 2015	*	-	*	*	-	*	-	4
Magan et al, 2019	-	-	-	*	-	*	*	3
Woodward et al, 2020	-	-	-	*	-	*	*	3
Lartey et al., 2018	-	-	-	*	-	*	*	3
Tesfatsion et al, 2015	-	-	-	*	-	*	-	2
Neuhann et al, 2001	-	-	-	*	-	*	-	2