

ORIGINAL RESEARCH ARTICLE

Diabetic dyslipidaemia and its predictors among hyperglycaemic patients in South Africa: A systematic review and meta-analysis

Mashudu Nemukula^{1,2*}, Fentahun Adane³, Arun Kumar Malaisamy², Themba Daniel Sambo¹, Madikana Bradley Moshokoa⁴, Sonwabiso Mema⁵, Neel Sarovar Bhavesh², Harold Majane⁶, and Sechene Stanley Gololo¹

¹Department of Biochemistry and Biotechnology, School of Science and Technology, Sefako Makgatho Health Sciences University, Pretoria, South Africa

²Transcription Regulation Group, International Centre for Genetic Engineering and Biotechnology, New Delhi, India

³Department of Anatomy, School of Medicine, College of Medicine and Health Science, University of Rwanda, Kigali, Rwanda

⁴Department of Neurosurgery, School of Medicine, Sefako Makgatho Health Sciences University, Pretoria, South Africa

⁵Department of Family Medicine, Tshwane District Hospital, Pretoria 0084, South Africa

⁶Department of Human Physiology, School of Medicine, Sefako Makgatho Health Sciences University, Pretoria, South Africa

***Corresponding author:**

Mashudu Nemukula
(mashudu.nemukula@smu.ac.za)

Citation: Nemukula M, Adane F, Malaisamy AK *et al.* Diabetic dyslipidaemia and its predictors among hyperglycaemic patients in South Africa: A systematic review and meta-analysis. *Eurasian J Med Oncol.* 2026;10(4):025380402. doi: 10.36922/EJMO025380402

Received: September 17, 2025

Revised: November 15, 2025

Accepted: December 1, 2025

Published online: June 19, 2026

Copyright: © 2026 Author(s). This is an Open-Access article distributed under the terms of the Creative Commons Attribution License, permitting distribution, and reproduction in any medium, provided the original work is properly cited.

Publisher's Note: AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract

Introduction: Diabetic dyslipidaemia is a growing public health concern, especially among patients with diabetes. Despite advancements in diabetes management, diabetic dyslipidaemia remains prevalent and contributes to increased morbidity and mortality rates. Understanding its impact, particularly in South Africa, is crucial for developing effective interventions.

Objective: The review aims to address these gaps by systematically analysing existing published studies on diabetic dyslipidaemia, estimating its pooled prevalence, and identifying factors associated with its occurrence.

Methods: The systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist guidelines. Eligible studies were sought in electronic databases using search keywords. The Joanna Briggs Institute critical appraisal checklist tool was used to assess the quality of studies. STATA 17 software was used for meta-analysis to compute the pooled prevalence with a 95% confidence interval.

Results: Ten eligible studies were included. The pooled prevalence of diabetic dyslipidaemia among the South African hyperglycaemic population was 71.56% (95% CI: 56.61–86.52). Sub-group analysis by region reported that the highest prevalence of diabetic dyslipidaemia was 89% (95% CI: 82.87–95.13) in the Western Cape province. The urban population was projected to have the highest prevalence of 79.97% (95% CI: 64.80–95.14). The most frequently reported pattern of diabetic dyslipidaemia was elevated LDL-C, accounting for 59% (95% CI: 43.58–75.93) of the studies. Body mass index (BMI) was the most reported predictor across multiple studies.

Conclusion: These findings of the current study suggest that there is an urgent need to strengthen lipid management strategies in the South African diabetic population.

Keywords: Diabetic dyslipidaemia; South Africa; Predictors; Systematic review; Meta-analysis

1. Introduction

Diabetic dyslipidaemia (DD) is a major public health concern worldwide, particularly among the diabetic population.^{1,2} Globally, DD has been recognised as a contributing factor to non-communicable diseases and plays a fundamental role in the pathogenesis of multiple atherosclerotic cardiovascular diseases (ACVDs) such as coronary artery disease (CAD), cerebrovascular accident (CVA), and peripheral arterial disease (PAD).^{3–5} Moreover, DD is associated with a higher mortality rate.⁶ Despite the persistent efforts to improve management of diabetes and its associated complications, DD remains a major health concern, contributing significantly to the burden of morbidity and mortality among the diabetic population.⁷

In low- and middle-income countries, the surge in diabetes cases is estimated to reach 1.3 billion by 2050, if the current trends continue.⁸ Among individuals with diabetes, DD is frequently observed, a lipid metabolism disorder characterised by hypertriglyceridaemia, including decreased high-density lipoprotein cholesterol (HDL-C) and a higher proportion of small dense low-density lipoprotein cholesterol (sdLDL-C).^{2,9–11} Moreover, studies have indicated that these lipid metabolism disorders exacerbate the risk of developing ACVD among the diabetic population, particularly those with type 2 diabetes mellitus (T2DM).^{12,13}

South Africa, akin to several other developing nations, faces a growing prevalence of T2DM, accompanied by an increased burden of DD.^{14,15} The South African Demographic and Health Survey indicates a significant increase in diabetes prevalence among adults, with studies suggesting that DD is the major metabolic disorder.^{14,16,17} Studies indicate that a significant proportion of South Africans with T2DM often exhibit poorly controlled lipid profiles, further exacerbating the risk of ACVD.^{15,18} It has been reported that diabetes contributed to approximately 5.4% of total mortality among South Africans in 2017, and many of these were linked with complications arising from poorly managed diabetes.¹⁹ The number of DD-related mortalities is expected to increase in the coming years if targeted interventions to combat DD are not implemented.

In addition to the complications associated with poorly managed lipid profiles in T2DM individuals, there are major health concerns related to undiagnosed DD, especially among individuals with early-onset diabetes. Individuals with early-onset diabetes present with susceptibility to physiological and metabolic disruptions defined by increased free fatty acid flux secondary to insulin resistance, and aggravated by elevated inflammatory adipokine levels, which can exacerbate DD.^{20,21} These individuals are generally more likely to engage in unhealthy lifestyle practices, such as improper dietary intake, lack of physical activity, and inadequate diabetes treatment adherence, which subsequently contribute to impairment of the lipid profile.^{22,23}

In South Africa, effective screening, early detection, and treatment of DD is of vital public health significance, considering the reported high prevalence of obesity and sedentary lifestyle behaviours.^{24,25} Moreover, some studies have suggested that DD remains undiagnosed or poorly managed among the South African diabetic population, highlighting the gap in healthcare services and awareness. In addition, social factors such as socioeconomic status, level of education, and access to healthcare are known to influence the prevalence and management of DD in this population.²⁶ This observation was corroborated by a study conducted by Owolabi *et al.*,²⁷ which indicated poor rates of lipid screening, with only 8.9% of lipid values reported from a rural Eastern Cape survey. This finding aligns with the study by Raal *et al.*,²⁸ which reported suboptimal lipid management and treatment intensity, indicating that 50.3% of statin-treated patients in the DYSLipidaemia International Study South Africa sample fail to achieve LDL-C targets.

Although the South African Dyslipidaemia Guideline Consensus Statement (2018), formulated by the South African Heart Association and the Lipid and Atherosclerosis Society of Southern Africa, for the management of dyslipidaemia²⁹; there is limited evidence regarding the efficacy of these guidelines, attributed to various influencing factors, including implementation, adherence by healthcare providers, patient compliance, and systemic challenges within the healthcare system. Studies

indicate that many diabetic individuals fail to achieve lipid targets, highlighting the need for personalised and customised population-based interventions.³⁰ Predictors associated with DD include genetic predisposition, poor glycaemic control, obesity, and lifestyle factors such as smoking, alcohol consumption, improper dietary intake, and physical inactivity.³¹ Furthermore, healthcare system challenges, including limited access to lipid-lowering therapies and inadequate patient education, complicate the management of DD.³²

Understanding the prevalence and predictors of DD in SA is significant for developing effective, evidence-based interventions. To the best of our knowledge, there is limited evidence from systematic reviews and meta-analyses that investigated the prevalence and predictors of DD in South Africa, particularly among the diabetic populations. There is a scarcity of population-based data regarding lipid profiles among diabetes patients in South Africa. Secondly, existing studies employ inconsistent diagnostic criteria and lipid threshold cutoffs for defining DD, which impair the ability to compare findings across studies. Thirdly, heterogeneous reporting practices and the scarcity of province-level data further hinder the ability to estimate the pooled prevalence of DD. Consequently, these constraints have probably led to a deficit of systematic reviews and highlighted the necessity for further epidemiological studies to provide reliable pooled estimates of the prevalence and determinants of DD. Thus, this systematic review coupled with a meta-analysis aims to address these gaps by systematically analysing existing published studies on DD, estimating its pooled prevalence and identifying factors associated with its occurrence. The findings are intended to inform targeted intervention efforts aimed at reducing the burden of DD and its associated complications in individuals with diabetes in South Africa.

2. Materials and methods

2.1. Protocol registration and search strategy

This study protocol was registered in the international database for systematic reviews PROSPERO (registration number CRD42024614221). This systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines³³ to systematically identify, select, and include relevant studies on DD and its determinants among hyperglycaemic patients in South Africa. The search keywords were conceptualised systematically using a combination of Medical Subject Headings (MeSH) and terms related to DD, its predictors, hyperglycaemia, and the South African population. These keywords were then evaluated and refined through

consultation with experts to ensure comprehensive coverage of the topic. Boolean operators “OR” and “AND” were applied to combine keywords, synonyms, and related terms. The database search was carried out between December 2024 and May 2025. The search strategy was implemented using international scholarly databases (PubMed/MEDLINE, Embase, Scopus, Web of Science, ScienceDirect, African Index Medicus, Google Scholar) and local databases (African Journals Online and SABINET) to identify relevant South African articles published in English. The literature search was conducted using the following keywords: “(Diabetic dyslipidaemia OR Lipid abnormalities OR Lipid metabolism disorders) AND (Lipid profile OR Triglycerides OR High-density lipoprotein cholesterol OR Low-density lipoprotein cholesterol) AND (Diabetes mellitus OR Hyperglycaemia OR Type 2 Diabetes Mellitus OR T2DM) AND Predictors OR Risk factors OR Determinants OR Contributing factors OR Associated factors) AND (South Africa OR Eastern Cape OR Free State OR Gauteng OR KwaZulu-Natal OR Limpopo OR Mpumalanga OR North West OR Northern Cape OR Western Cape). Relevant studies published before December 2024 were included.

2.2. Screening and eligibility criteria

The review employed a systematic methodology. Initially, a screening was performed based on title and abstract to identify relevant studies on DD and its predictors among hyperglycaemic patients in South Africa. Two independent reviewers (M.N. and F.A.) carefully scanned and read the titles, abstracts, and keywords of all the articles extracted from the databases to assess whether they were relevant and eligible for consideration. Articles unrelated to the focus of the review were excluded. Any discrepancies between the reviewers were resolved by consensus and involvement of a third reviewer (A.K.M). Furthermore, the full text of the article was comprehensively evaluated and cross-checked for eligibility. At each stage, the rationale for eliminating studies that failed to meet the inclusion criteria was documented to maintain transparency in the review process.

Studies were considered if they were conducted in South Africa or in South African Provinces (Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, North-West, Northern Cape, and Western Cape), and reported on prevalence, lipid metabolic disorders, and predictors of DD among the hyperglycaemic population. In addition, studies published in peer-reviewed journals that include full text written in English were considered. Studies conducted outside South Africa were excluded. Studies reporting on conditions unrelated to DD, without an abstract and full text, or not peer-reviewed, were

excluded. In addition, studies that were qualitative and lacked quantitative details, conference summaries, or systematic reviews were excluded. Studies with a minimum sample size threshold of $n < 50$ were considered, or those without a clear sample size were excluded to ensure data quality and representativeness. The studies were either eliminated from preliminary analysis or retained solely for sensitivity analysis to prevent the undue influence of imprecise estimates, ensuring only those studies with adequate sample sizes contributed to the pooled prevalence and upheld robust meta-analysis estimates.

2.3. Data extraction

The subsequent data were gathered utilising a standardised data collection form developed in accordance with the Cochrane Handbook for Systematic Reviews of Interventions: Surname of the first author, publication year, study location, study setting, study design, study population, sample size, mean age, overall prevalence of DD, patterns of DD, and predictors of DD. Two independent reviewers (M.N. and F.A.) extracted the data from each article and documented it in an Excel spreadsheet. The data extraction process was standardised using a codebook that defined each variable and outlined the extraction rules for each variable. Cohen's kappa statistics were employed to evaluate the level of agreement between the reviewers.

2.4. Quality assessment

The Joanna Briggs Institute critical appraisal checklist tool, tailored for prevalence studies, was employed to evaluate the quality of selected studies, which is accessible at <https://jbi.global/critical-appraisal-tools>.³⁴ To achieve this, nine critical questions from the checklist tool were surveyed for each selected study by two independent reviewers (M.N. and F.A.) following a blinded review approach. The survey comprised the subsequent enquiries: Was the sampling frame suitable for the target population? Were the study subjects sampled appropriately? Was the sample size sufficient to yield reliable prevalence estimates? Were the study participants and setting sufficiently detailed? Was data analysis conducted with sufficient coverage of the identified sample? Were valid methods used to identify the condition? Was the condition measured in a standard, reliable way for all study participants? Was an appropriate statistical analysis conducted to ensure accurate results? Was the response rate adequate, and if not, was it managed appropriately? The question included four possible response choices, which were "Yes" or "No" or "Unclear," or "Not applicable." The reviewers assessed the quality of the included studies using a scoring system, categorising scores of 0–3 as low-quality, 4–6 as moderate-quality, and 7–9 as high-quality studies. Any discrepancies were

discussed and resolved through consensus with the other two reviewers (A.K.M. and T.D.S.).

2.5. Statistical analysis

Relevant data extracted from the studies using the standardised data collection form were exported to STATA version 17 software (StataCorp LLC, College Station, TX, USA) for analysis. The main key features of STATA version 17 that were leveraged in the study included data management tools, meta-analysis tools, heterogeneity analysis, publication bias assessment, subgroup and sensitivity analysis, and graphical output representation. The data retrieved from the studies were documented in a descriptive table to illustrate the study characteristics. The table included information including authors, publication year, location of the study, study participants, demographic type, sample size, and overall prevalence (%). The pooled prevalence of DD within the South African hyperglycaemic population was analysed and illustrated in a forest plot projecting the standard error and 95% confidence interval of the individual study estimates. The presence of statistical heterogeneity on the prevalence estimates was evaluated using I^2 statistics (Der Simonian–Laird approach). Sensitivity analysis was used to identify probable sources of variance in the pooled prevalence of DD by sequentially removing individual studies. Publication bias was evaluated using graphical funnel plots and statistically examined via Egger's or Begg's tests, where a p -value < 0.05 indicated significant bias. A meta-analysis was conducted to assess the influence of predictors, including the year of study and sample size, on the prevalence of DD.

3. Results

3.1. Search results

One hundred published articles were retrieved from PubMed, Embase, Scopus, ScienceDirect, Google Scholar, and other databases, of which 50 were excluded due to duplication from the initial records. The titles and abstracts of the remaining 50 articles were scrutinised to identify individuals with diabetes in South Africa and its provinces, resulting in the exclusion of 29 articles that were deemed irrelevant. The remaining 21 abstracts of articles were identified and screened for eligibility. The full text screening was performed for studies reporting on the diabetic dyslipidaemia prevalence and its predictors among hyperglycaemic patients in South Africa, resulting in 10 eligible articles that were included in meta-analysis. Among various assessments, 11 articles were excluded due to insufficient in-depth analysis, absence of quantitative data, or inadequate data on the prevalence of diabetic dyslipidaemia. Figure 1 illustrates the PRISMA flow chart for identification and selection of relevant studies.

3.2. Characteristics of the original articles

The systematic review and meta-analysis included 10 original articles that revealed the prevalence of diabetic dyslipidaemia, including its predictors, among the hyperglycaemic population in South Africa. The characteristics of the 10 original articles are summarised in Table 1. The studies that were part of the meta-analysis were conducted before December 2024, assessing a total sample of 2868 hyperglycaemic South Africans. The studies summarised predominantly adopted a cross-sectional and retrospective research design, investigating a mix of rural and urban populations across South Africa. Out of the 10 studies, six were conducted in an urban population setting^{14,18,28,35–38}, and four in a mixed/semi-urban population setting.^{15,17,39,40} Urban populations displayed higher prevalence percentages compared to the rural populations, with mixed populations also displaying a substantial percentage. Sample sizes ranged from 62 participants to 754 participants.^{32,35} The reported prevalence percentages of DD spanned from as low as 13.6% to as high as 93.5%.^{14,39} The studies were of high quality, with a score of approximately 7 or above.

3.3. Prevalence of diabetic dyslipidaemia among hyperglycaemic populations in South Africa

Figure 2 summarises the results from 10 research studies evaluating a specific effect with 95% confidence intervals (CIs). The overall pooled prevalence of DD among the hyperglycaemic population in South Africa estimated from the random-effects Der Simonian–Laird model is 71.56% (95% CI: 56.61–86.52), with a statistically significant heterogeneity across studies ($I^2 = 99.0\%$, $p < 0.001$). The prevalence of DD from individual studies ranged from 13.60% (95% CI: 8.54–18.66)³⁹ to 93.50 (95% CI: 90.08–96.92).¹⁴ The CIs for a majority of studies were comparatively narrow, except for a few studies such as Mashele *et al.*³⁹ with broader intervals and more variability. In addition, a univariate meta-regression model was used to explore potential sources of heterogeneity, considering variables such as year of publication and sample size. No statistically significant variables were registered, and no publication bias was identified through the Begg's and Egger's tests.

3.4. Heterogeneity and subgroup analysis

The provincial and population type-based subgroup analysis was performed to manage the heterogeneity among the studies. South Africa comprises nine provinces, which vary considerably in healthcare access and socioeconomic status, adversely affecting lipid profiles and increasing the risk of ACVD among hyperglycaemic patients. In addition, meta-regression analysis with year of publication and prevalence as variables was performed. The subgroup analysis by region showed the highest prevalence of DD

was reported in the studies conducted in the West Cape province 89.00% (95% CI: 82.87–95.13), followed by the Free State province 86.70% (95% CI: 81.13–92.27), and studies conducted across South Africa 81.35% (95% CI: 72.25–90.46). Gauteng province reported the lowest prevalence of 62.86% (CI: 37.74–87.99).

Gauteng province showed significant heterogeneity across studies ($I^2 = 99.4\%$, $p < 0.001$), while the overall pooled effect across all provinces was 71.56% (95% CI: 56.61–86.52), with no significant heterogeneity between subgroups ($p = 0.156$) (Figure 3). Out of 10 studies included, 6 studies were from the Gauteng province, two studies were from across South Africa, one study from the Western Cape province, and one study from the Free State province. No studies from the Limpopo province, Mpumalanga Province, North-West province, and Northern Cape province were included.

Subgroup analysis based on author and population type displayed a significant variation in the prevalence of DD. Based on subgroup analysis of population type, the highest prevalence of DD was observed in studies conducted in the urban population type (79.97% [95% CI: 64.80–95.14]), and the lowest prevalence of DD was reported (58.90% [95% CI: 25.97–91.82]). The heterogeneity and the overall effect observed for population type subgroup analysis displayed no significant differences ($p = 0.255$) (Figure 4).

3.5. Patterns of diabetic dyslipidaemia among the hyperglycaemic population in South Africa

Data from five studies reported the prevalence of hypercholesterolaemia, with rates varying from 27% (95% CI: 20.86–33.15)³⁸ to 56% (95% CI: 46.27–65.73).¹⁵ The overall pooled prevalence of hypercholesterolaemia computed using the Der Simonian–Laird random-effect model is 45% (95% CI: 33.55–56.46), with a significant heterogeneity ($I^2 = 93.6\%$, $p < 0.001$) (Figure 5A). Across nine studies, the prevalence of hypertriglyceridaemia varied, with the lowest prevalence estimate reported at 33.50% (95% CI: 26.96–40.04)³⁸ and the highest prevalence estimate reported to be 64% (95% CI: 54.59–73.41).¹⁵ The overall pooled prevalence of hypertriglyceridaemia was estimated to be 48% (95% CI: 41.47–55.77), with a significant heterogeneity ($I^2 = 91.8\%$, $p < 0.001$) among studies (Figure 5B).

The prevalence of reduced HDL-C as reported by nine studies varied between 38% (95% CI: 33.34–42.66)²⁸ and the highest prevalence estimate reported to be 85.40% (95% CI: 80.18–90.62).³⁹ The overall pooled prevalence estimates of reduced HDL-C, computed using Der Simonian–Laird random-effect model, are 53.07% (95% CI: 42.53–63.61),

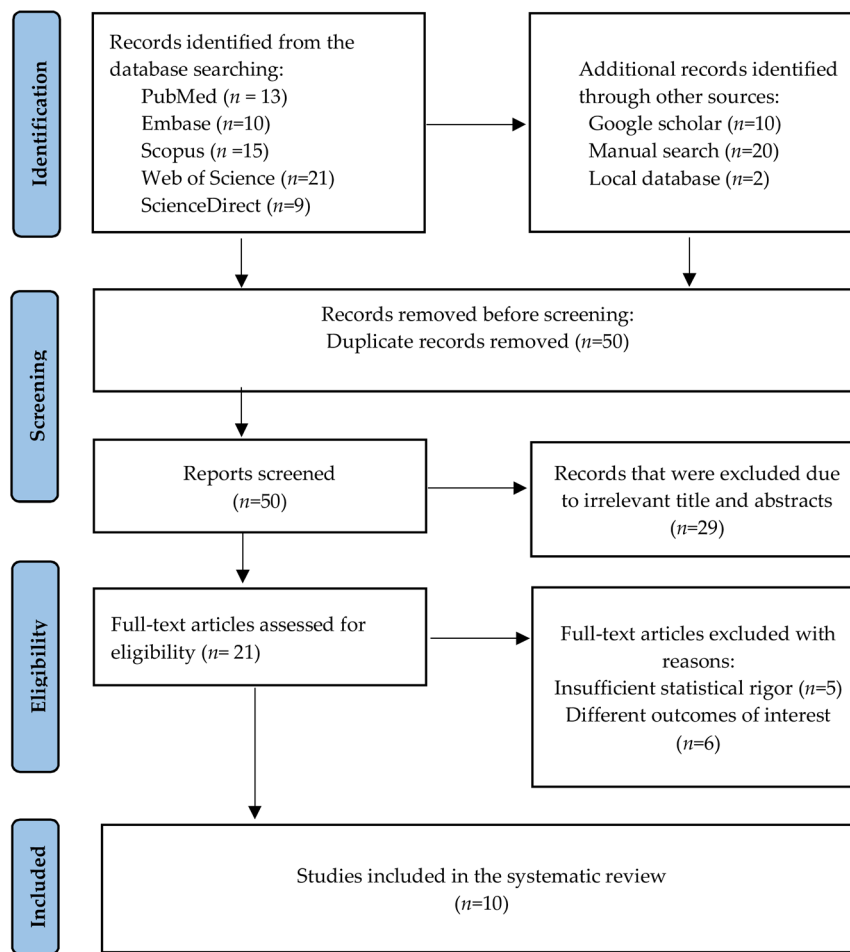


Figure 1. Flow diagram illustrating the identification and selection of studies for the systematic review and meta-analysis of prevalence and predictors of diabetic dyslipidaemia among type 2 diabetic population in South Africa

Table 1. Descriptive summary of the twelve included studies in the systematic review and meta-analysis of the prevalence of diabetic dyslipidaemia among the South African hyperglycaemia population

Author	Year of publication	Region	Study design	Sample size	Cases	Prevalence (%)	JBL Score
Vezi <i>et al.</i> ³⁵	2005	Gauteng	Cross-sectional	62	56	90.3	8
Kalk <i>et al.</i> ³⁷	2008	Gauteng	Cross-sectional	754	378	50.1	6
Raal <i>et al.</i> ²⁸	2013	Across South Africa	Cross-sectional,	416	358	86	7
Daya <i>et al.</i> ¹⁴	2017	Gauteng	Cross-sectional	200	187	93.5	8
Mashele <i>et al.</i> ³⁹	2019	Gauteng	Cross-sectional	176	24	13.6	8
Naidoo <i>et al.</i> ³⁸	2020	Gauteng	Retrospective	200	147	73.5	7
Moshane <i>et al.</i> ⁴⁰	2020	Gauteng	Retrospective	203	114	56.3	6
Omodanisi <i>et al.</i> ¹⁵	2020	Western Cape	Cross-sectional	100	89	89	8
Masilela <i>et al.</i> ¹⁷	2022	Across South Africa	Cross-sectional	614	471	76.7	9
Pitso <i>et al.</i> ¹⁸	2023	Free State	Retrospective	143	124	86.7	8

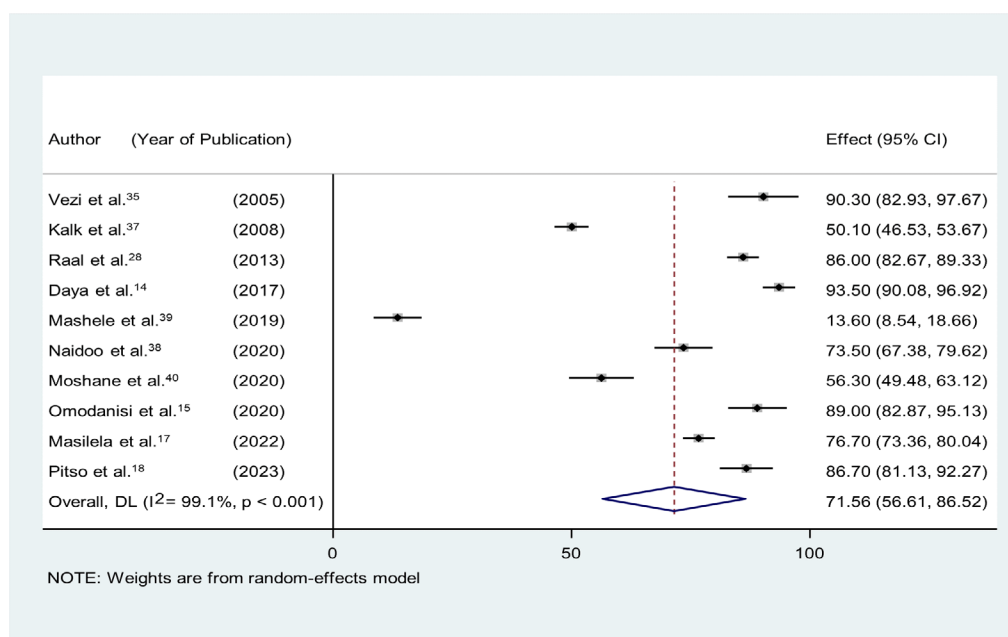


Figure 2. Forest plot of the pooled prevalence of diabetic dyslipidaemia among the hyperglycaemic population in South Africa

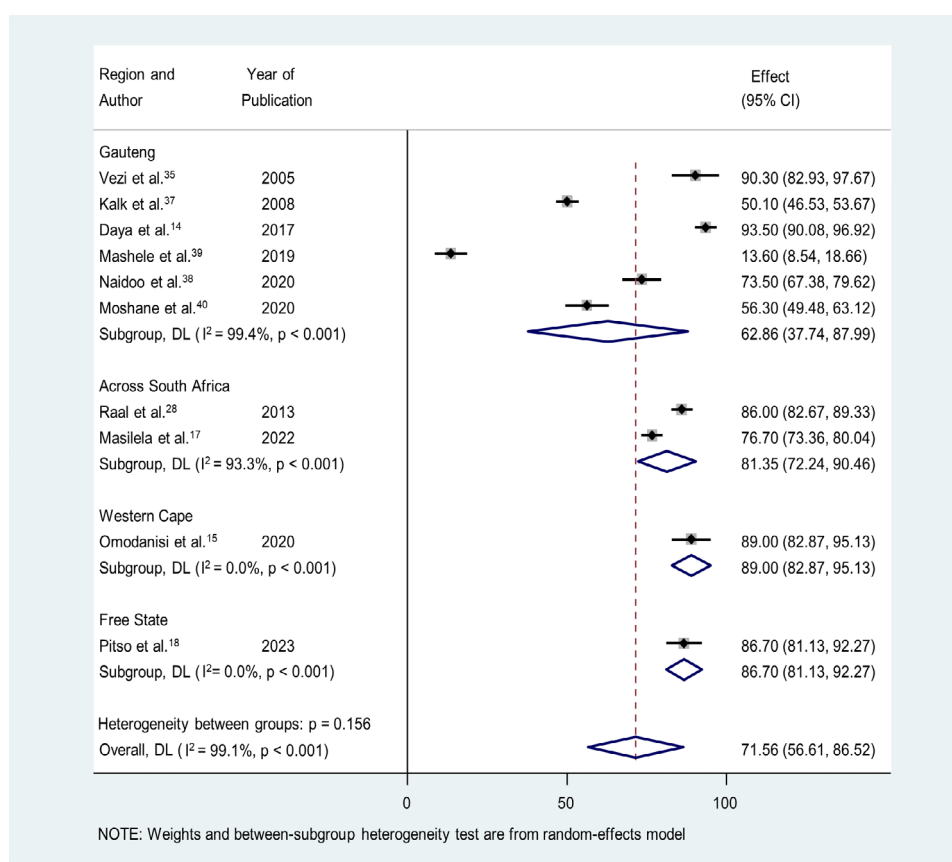


Figure 3. Forest plot of the subgroup analysis of the prevalence of diabetic dyslipidaemia in different provinces in South Africa

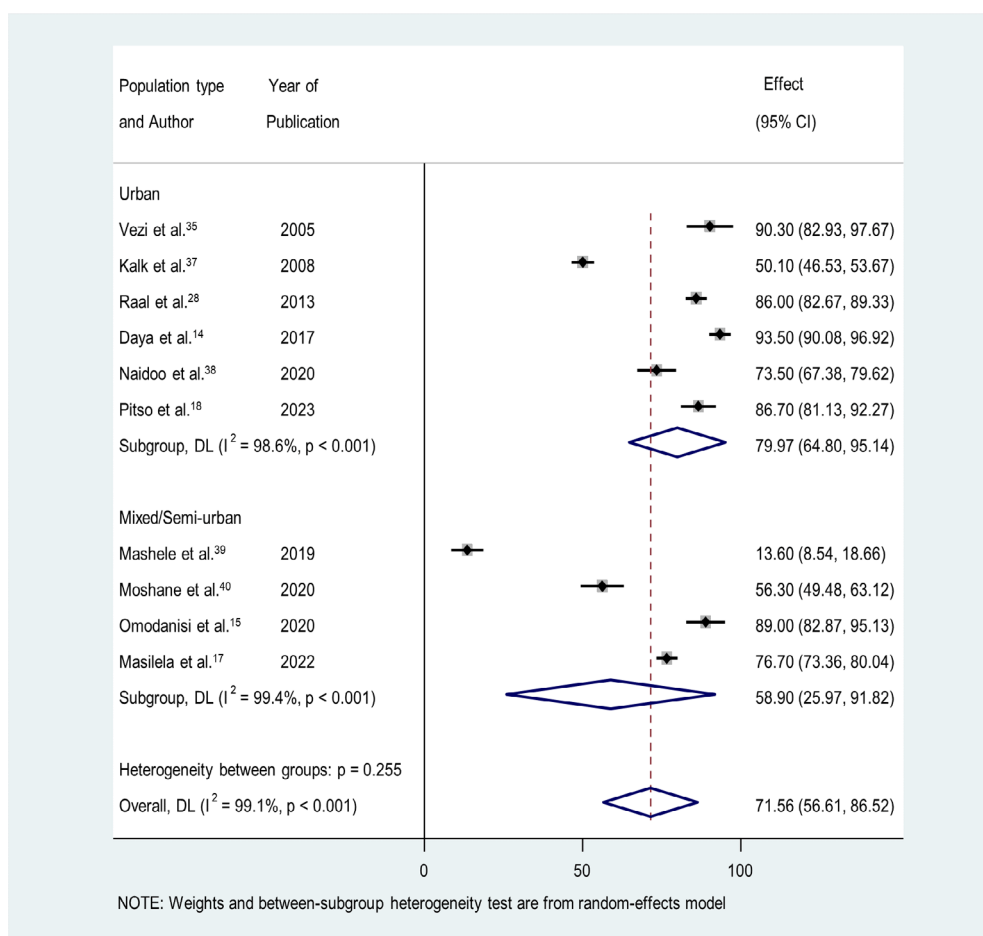


Figure 4. Forest plot of the subgroup analysis of the prevalence of diabetic dyslipidaemia according to population type in South Africa

with a substantial variability in effect sizes among studies ($I^2 = 96.5\%$, $p < 0.001$) (Figure 5C). The prevalence of elevated LDL-C was observed across seven studies, with the lowest prevalence reported at 28.30% (95% CI: 21.47–35.13)³⁹ and the highest at 76.50% (95% CI: 70.62–82.38).¹⁴ The computed overall pooled prevalence of elevated LDL-C is 59% (95% CI: 43.58–75.93), with a significant heterogeneity among studies ($I^2 = 98.0\%$, $p < 0.001$) (Figure 5D).

3.6. Predictors of diabetic dyslipidaemia among the hyperglycaemic individuals in South Africa

This paper does not include a meta-analysis for associated predictors because the data were incompatible with a two-by-two table format. We performed a thorough analysis of the relevant variables from all included studies. The predominant reported variables were body mass index (BMI)^{17,18,28,32,37}, succeeded by inadequate glycaemic control as indicated by Pitso *et al.*¹⁸ and Kalk *et al.*³⁷ Ethnicity was

also reported as one of the significant associated predictors by the following studies.^{17,28} In the current review, the duration of diabetes³⁹, age⁴⁰, and gender¹⁸, were the least reported associated predictors across the included studies.

4. Discussion

Individuals with diabetes are prone to several health complications, including metabolic disorders such as insulin resistance and non-alcoholic fatty liver disease, as well as DD and endothelial dysfunction.^{41,42} These metabolic disorders are recognised to markedly elevate the risk of ACVD, such as CAD, CVA, and PAD.^{43,44} DD, a lipid metabolism disorder characterised by hypertriglyceridaemia, decreased HDL-C, and elevated LDL-C, is one of the most common metabolic disorders observed in the diabetic population as a result of poor glycaemic control, detrimental lifestyle choices, including poor dietary intake, lack of physical activity, and inadequate diabetes treatment adherence.^{45–48}

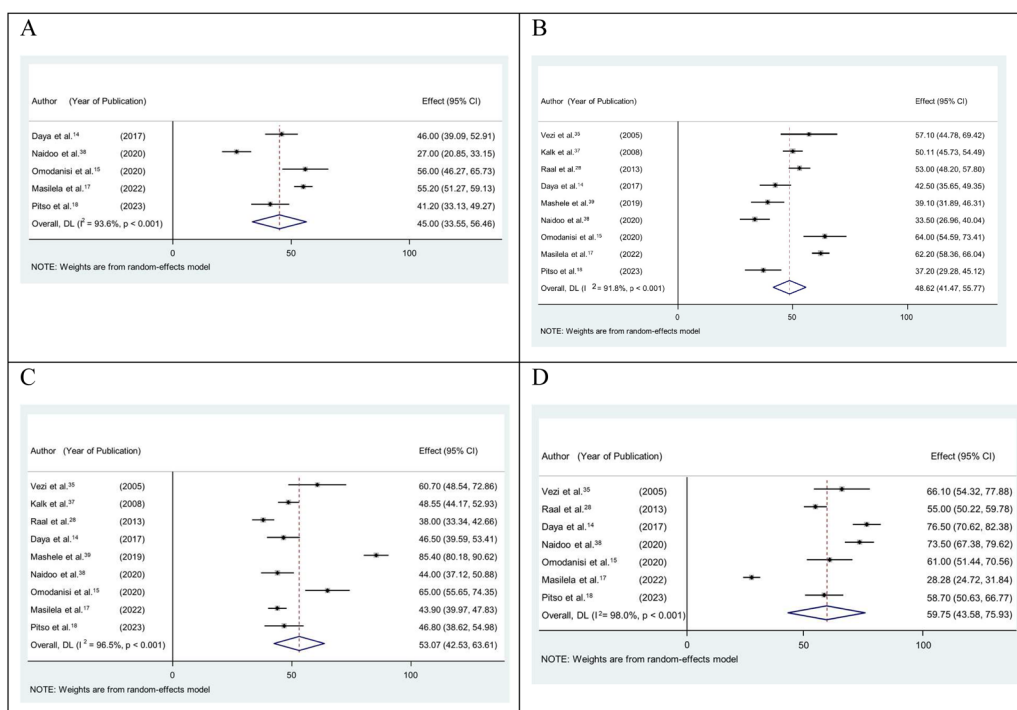


Figure 5. Forest plot presenting the pooled prevalence of patterns of diabetic dyslipidaemia among the hyperglycaemic populations. (A) Hypcholesterolaemia; (B) hypertriglyceridaemia; (C) reduced high-density lipoprotein; and (D) elevated low-density lipoprotein in South Africa.

South Africa has initiated various programs to enhance diabetes care, including national treatment guidelines and preventive strategies for cardiovascular diseases, in response to the increasing rates of diabetes and related metabolic issues.^{49,50} Nevertheless, it faces a high prevalence of diabetes, with over 4.5 million people affected by lipid metabolic disorders related to the condition, making it one of the most impacted countries in Sub-Saharan Africa.⁵¹

For this reason, the current systematic review and meta-analysis were conducted to assess the pooled prevalence of DD and its predictors among the hyperglycaemic population in South Africa. Through a rigorous identification and screening process, 10 research articles that met the eligibility criteria were included in this study, involving a total of 2,868 participants. In the current study, the pooled prevalence of DD was estimated to be 71.56% among the diabetic population in South Africa. The result indicates that over 50% of the diabetic population in South Africa suffers from lipid metabolism disorders, which contribute to ACVD. Among many other reasons, insulin resistance and chronic hyperglycaemia, including chronic low-grade inflammation and obesity, may account for the high prevalence of lipid metabolic disorders among the South African diabetic population. Equally important, poor glycaemic control and the effects of certain

medications also play a role in lipid metabolism disorders. Moreover, effects of these possible mechanisms include behavioural issues such as inadequate statin dosing, poor treatment adherence and insufficient clinical monitoring, which create a major treatment gap. The DYSLipidaemia International Study analysis conducted by Ntusi *et al.*⁵² revealed comparable results, showing that nearly 50% of South African patients undergoing statin therapy did not meet LDL-C objectives. The analysis further highlighted gaps in treatment and care for lipid management. All these factors contribute to the high burden of DD among the South African diabetic population.

The observed pooled prevalence of DD in our study is comparable to the findings reported in other African studies on the prevalence of DD among the diabetic population. However, compared with studies in other African countries, our findings were lower than the reported prevalence in Zimbabwe (83.6%),⁵³ Kenya (86.1%),⁵⁴ Nigeria (89%),⁵⁵ and Somalia (92.8%),⁵⁶ and higher than the reported prevalence in Ghana (34.7%)⁵⁷ and Malawi (58%).⁵⁸ Furthermore, in contrast to international studies, the findings of our current study were higher than the prevalence reported in China (48.27%),⁵⁹ Shanghai (29.10%),⁶⁰ and the United States (53%).⁶¹ This variation could be influenced by several factors, such as differences in healthcare access, nutritional

profile, lifestyle factors, and genetic predisposition related to lipid metabolism disorders among different populations. The observed findings suggest that the existing strategies to manage DD are not adequately effective in reducing lipid metabolic disorders in South African diabetic populations. Furthermore, this observation warrants an investigation into the public health challenges posed by DD. The reported heterogeneity among the included studies was significantly high, indicating disparities in the reported prevalence estimates. Disparities in study methods, study setting, diagnostic criteria for DD, population characteristics, and sample sizes may have contributed to this observation. It is essential to note that we did not conduct a Hartung-Knapp analysis to provide a more conservative estimate of the pooled prevalence, as this would account for between-study differences.

In the current study, subgroup analysis shows that the prevalence of DD among diabetic South Africans varies across population types with no significant heterogeneity differences. The urban population had the highest DD prevalence, and the mixed/semi-urban population had the lowest. We did not have studies conducted among the rural population. While the findings suggest that population type may not appear to be a significant contributor for the prevalence of DD, many studies have affirmed that individuals living in urban areas are likely to have an uncontrolled diabetes and lipid metabolic disorder compared to those in rural areas, as a result of unhealthy lifestyle choices, unhealthy dietary intake, a lack of physical activity, and increased prevalence of obesity.^{62–65} Moreover, contributing factors such as socioeconomic status, including access to healthcare and environmental factors, might also play a more crucial role in the increased prevalence of DD.^{66,67} To some extent, these factors contribute to poor glycemic control, which subsequently affects the metabolism of lipids. Research conducted by Joffe *et al.*⁶⁸ indicates that DD was significantly prevalent among Black South Africans with T2DM residing in low socioeconomic conditions, suggesting that limited access to healthcare and health education may exacerbate lipid metabolic problems. Collectively, these factors influence the regional disparities in the prevalence of DD, including its management.

The most common reported lipid metabolic disorder of DD in the current study was elevated LDL-C, followed by reduced HDL-C, hypertriglyceridaemia, and hypercholesterolaemia. Our findings agreed with other existing studies that elevated levels of LDL-C are the most frequent lipid metabolic disorder among the diabetic population.^{58,69,70} Furthermore, according to multiple studies, elevated LDL-C is the hallmark of DD and is

strongly associated with increased risk of ACVD among the diabetic population, particularly in T2DM patients.^{9,70}

The present study reported an overall prevalence of 53.07% for reduced levels of HDL-C and 48.62% for hypertriglyceridaemia among the South African diabetic population. These findings suggest that more than half of the studied population fail to achieve the desirable target of HDL-C levels and have hypertriglyceridaemia. HDL-C is regarded as good cholesterol, which plays a protective role against ACVD, by facilitating the removal of excessive cholesterol from the bloodstream to the liver for excretion⁷¹, while triglycerides are nonpolar lipid molecules, which serve as a source of energy for the normal physiological function of the body.⁷² Both reduced levels of HDL-C and hypertriglyceridaemia are well-documented lipid abnormalities associated with increased risk of atherosclerosis, including CAD, CVA, and PAD.⁷³ This observation might be driven by factors such as age, gender, improper dietary intake, lack of physical activity, obesity, and insulin resistance, which subsequently lead to DD. As a result, managing the levels of reduced HDL-C and hypertriglyceridaemia is very critical for preventing DD-related complications such as ACVD. While the prevalence of elevated levels of LDL-C, reduced levels of HDL-C, and hypertriglyceridaemia is significantly high, the computed overall prevalence of hypercholesterolaemia (45%) suggests that nearly half of the studied population achieves the desirable target of total cholesterol. Total cholesterol is defined as a sum of different cholesterol fractions in a person's blood. Although hypercholesterolaemia is known to contribute to the buildup of plaque in the arteries and restrict blood flow, which eventually leads to atherosclerosis, they are not always a significant predictor of ACVD. Thus, when combined with elevated levels of LDL-C, reduced levels of HDL-C, and hypertriglyceridaemia, they increase the risk of ACVD.^{74–76} In summary, maintaining a good lipid profile in individuals with DD is very crucial to reducing the risk of ACVD. Regular and early detection through screening and proactive management of DD are of great importance for long-term health.

In the current analysis, BMI was identified as the most reported predictor across multiple studies. The findings are consistent with the well-established association between obesity and DD, where BMI is known to contribute to insulin resistance, impairment of lipid metabolism, and heightened risk of ACVD in individuals with diabetes.^{77–79} Poor glycaemic control was also identified as a key predictor, as indicated by several studies.^{18,37} Chronic hyperglycaemia is known to contribute to lipid abnormalities, characterised by hypertriglyceridaemia,

reduced HDL-C, and elevated LDL-C, which are associated with the increased risk of ACVD.⁸⁰ Ethnicity was also reported as a significant predictor in multiple studies.^{17,28} This observation could be attributed to factors such as genetic predisposition, nutritional profile, and socioeconomic status. Existing studies have affirmed the impact of ethnicity on variation in lipid profiles among different ethnic groups.^{81–83} Duration of diabetes, age, and gender were the least reported in the current study. All these predictors are known to be significant factors for DD.^{46,84–86} Furthermore, considering that most Sub-Saharan African countries share susceptibility to similar socioeconomic and lifestyle risk factors, the observed patterns and predictors of DD in these studies may be pertinent not only to South Africa but also to other African countries undergoing comparable epidemiological transitions. These findings may thus establish a baseline for other African countries, where population-based data is limited, and could guide the formulation of standardised policies for the screening, management, and prevention of DD throughout the continent.

The strength of the current study lies in its nature as the first of its kind in South Africa, to systematically search for existing peer-reviewed studies for assessment of the prevalence of DD and its patterns among the hyperglycaemic population. Secondly, the identification and selection of the studies was conducted by more than one reviewer to ensure inclusion of all relevant studies meeting the inclusion criteria. Several limitations must be considered when interpreting the outcomes of the current analysis. The meta-analysis included a limited number of studies, drawn from only a few regions of South Africa. Some regions, including Limpopo province, KwaZulu-Natal province, Mpumalanga province, North-West province, and Northern Cape province, were underrepresented due to a lack of data. This observation suggests possible geographical disparity and limited geographic representation, which may affect the generalisation of the findings on the estimated pooled prevalence of DD. Another limitation is the variability in study designs, diagnostic criteria for DD, and laboratory thresholds among the included studies, which may have led to heterogeneity. We also did not perform a meta-analysis for associated predictors because most of the included studies did not provide odds ratios for these variables, which are necessary for quantitative synthesis of predictor effects. Another limitation is the possibility of missing studies, considering that only peer-reviewed and English-language studies were included, and not all databases were accessible for this review. This may have resulted in selection bias, causing the omission of existing research on the prevalence of DD from grey literature.

Future investigations should concentrate on executing population-based surveys and multicenter cohort studies in marginalised provinces to produce complete and accurate data, thereby addressing these constraints. Healthcare policymakers must incorporate standardised diagnostic criteria for lipids and consider studies from multilingual and diverse publication sources, hence enhancing the evidence base for DD in South Africa. Despite these limitations, the current study offers insights into the pooled prevalence of DD and its patterns among the hyperglycaemic population in South Africa.

5. Conclusion

This present analysis of 10 selected studies indicates a significant prevalence of DD within the hyperglycaemic population in South Africa. The prevalence of DD varied by province, with the Western Cape exhibiting the highest prevalence and Gauteng displaying the lowest. The review indicated that elevated LDL-C was the most common manifestation of DD among the hyperglycaemic population in South Africa. The findings underscore an urgent necessity to enhance lipid management strategies within the South African diabetic community as part of the diabetes care across healthcare institutions. Equally important, strategies to strengthen lipid management must include: (i) improving patient education on healthy dietary behaviours; (ii) promoting physical activity among diabetic patients; (iii) enhancing access to lipid-lowering therapies and promoting adherence to medication, as well as continuous follow-up; and (iv) integrating programs related to lifestyle modifications, including community-based interventions that address socioeconomic and cultural indicators. Collectively, the strategies could play a critical role in shaping evidence-based policies that will inform responsive intervention efforts aimed at reducing the burden of DD and its associated complications in diabetic patients in South Africa. Furthermore, we acknowledge the limitation of geographic representativeness, as most included studies were conducted in urban or semi-urban settings, with limited data from marginalised provinces and rural settings. However, the findings of the current study highlight the urgent need to expand efforts in screening and managing DD in marginalised provinces and rural areas. Therefore, we recommend that future studies and surveillance programs expand data collection to marginalised provinces and rural areas. Additionally, healthcare policymakers should emphasise the integration of community-based screening and management programs for DD into primary healthcare services in these regions. Moreover, data collection in marginalised provinces and rural settings should be prioritised to enhance the reporting of the pooled prevalence of DD and ensure that

health policies and interventions are tailored to the specific needs of these regions. These efforts will further promote equitable access to DD management across socioeconomic and geographical groups.

Acknowledgments

None.

Funding

None.

Conflict of interest

The author declares no conflict of interest

Author contributions

Conceptualization: Mashudu Nemukula, Fentahun Adane, Harold Majane

Data curation: Themba Daniel Sambo, Sonwabiso Mema

Formal analysis: Fentahun Adane, Mashudu Nemukula, Themba Daniel Sambo

Investigation: Mashudu Nemukula, Arun Kumar Malaisamy, Madikana Bradley Moshokoa, Sonwabiso Mema

Methodology: Mashudu Nemukula, Madikana Bradley Moshokoa, Arun Kumar Malaisamy

Supervision: Neel Sarovar Bhavesh, Harold Majane, Sechene Stanley Gololo

Writing—original draft: Mashudu Nemukula

Writing—review & editing: Neel Sarovar Bhavesh, Harold Majane, Sechene Stanley Gololo

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. World Health Organization. Diabetes. 2021. Accessed March 15, 2025. <https://www.who.int/news-room/fact-sheets/detail/diabetes>
2. ElSayed NA, Aleppo G, Aroda VR, *et al.* 10. Cardiovascular Disease and Risk Management: Standards of Care in Diabetes—2023. *Diabetes Care.* 2023;46(Supplement_1):S158-S190.

doi: 10.2337/dc23-S010

3. Einarson TR, Acs A, Ludwig C, Panton UH. Prevalence of cardiovascular disease in type 2 diabetes: a systematic literature review of scientific evidence from across the world in 2007–2017. *Cardiovasc Diabetol.* 2018;17(1):83. doi: 10.1186/s12933-018-0728-6
4. Budreviciute A, Damiani S, Sabir DK, *et al.* Management and Prevention Strategies for Non-communicable Diseases (NCDs) and Their Risk Factors. *Front Public Health.* 2020;8. doi: 10.3389/fpubh.2020.574111
5. Avdic T, Carlsen HK, Rawshani A, Gudbjörnsdottir S, Mandalenakis Z, Eliasson B. Risk factors for and risk of all-cause and atherosclerotic cardiovascular disease mortality in people with type 2 diabetes and peripheral artery disease: an observational, register-based cohort study. *Cardiovasc Diabetol.* 2024;23(1):127. doi: 10.1186/s12933-024-02226-x
6. Azagew AW, Abate HK, Mekonnen CK, Mekonnen HS, Tezera ZB, Jember G. Diabetic dyslipidemia and its predictors among people with diabetes in Ethiopia: systematic review and meta-analysis. *Syst Rev.* 2024;13(1):190. doi: 10.1186/s13643-024-02593-2
7. Xing L, Jing L, Tian Y, *et al.* Epidemiology of dyslipidemia and associated cardiovascular risk factors in northeast China: A cross-sectional study. *Nutr Metab Cardiovasc Dis.* 2020;30(12):2262-2270. doi: 10.1016/j.numecd.2020.07.032
8. International Diabetes Federation. *IDF Diabetes Atlas.* 10th edition. International Diabetes Federation; 2021.
9. Mooradian AD. Dyslipidemia in type 2 diabetes mellitus. *Nat Rev Endocrinol.* 2009;5(3):150-159. doi: 10.1038/ncpendmet1066
10. Taskinen MR, Borén J. New insights into the pathophysiology of dyslipidemia in type 2 diabetes. *Atherosclerosis.* 2015;239(2):483-495. doi: 10.1016/j.atherosclerosis.2015.01.039
11. Grundy SM, Stone NJ, Bailey AL, *et al.* 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA Guideline on the Management of Blood Cholesterol: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation.* 2019;139(25). doi: 10.1161/CIR.0000000000000625
12. Kaze AD, Santhanam P, Musani SK, Ahima R, Echouffo-Tcheugui JB. Metabolic Dyslipidemia and Cardiovascular Outcomes in Type 2 Diabetes Mellitus: Findings From the Look AHEAD Study. *J Am Heart Assoc.* 2021;10(7). doi: 10.1161/JAHA.120.016947

13. Warraich HJ, Rana JS. Dyslipidemia in diabetes mellitus and cardiovascular disease. *Cardiovasc Endocrinol*. 2017;6(1):27-32.
doi: 10.1097/XCE.0000000000000120
14. Daya R, Bayat Z, Raal F. Prevalence and pattern of dyslipidaemia in type 2 diabetes mellitus patients at a tertiary care hospital. *J Endocrinol Metab Diabetes South Afr*. 2017;22(3):31-35.
doi: 10.1080/16089677.2017.1360064
15. Omodanisi EI, Tomose Y, Okeleye BI, Ntwampe SKO, Aboua YG. Prevalence of Dyslipidaemia among Type 2 Diabetes Mellitus Patients in the Western Cape, South Africa. *Int J Environ Res Public Health*. 2020;17(23):8735.
doi: 10.3390/ijerph17238735
16. National Department of Health (NDoH), Statistics South Africa (Stats SA), South African Medical Research Council (SAMRC), ICF. *South Africa Demographic and Health Survey 2016*. Pretoria, South Africa: NDoH, Stata SA, SAMRC; Rockville, Maryland, USA: ICF; 2019.
17. Masilela C, Adeniyi OV, Benjeddou M. Prevalence, patterns and determinants of dyslipidaemia among South African adults with comorbidities. *Sci Rep*. 2022;12(1):337.
doi: 10.1038/s41598-021-04150-6
18. Pitso L, Mofokeng TRP, Nel R. Dyslipidaemia pattern and prevalence among type 2 diabetes mellitus patients on lipid-lowering therapy at a tertiary hospital in central South Africa. *BMC Endocr Disord*. 2021;21(1):159.
doi: 10.1186/s12902-021-00813-7
19. Statistics South Africa. *Mortality and Causes of Death in South Africa: Findings from Death Notification, 2017*. Pretoria, South Africa: Statistics South Africa; 2020.
20. Boden G. Obesity, insulin resistance and free fatty acids. *Curr Opin Endocrinol Diabetes Obes*. 2011;18(2):139-143.
doi: 10.1097/MED.0b013e3283444b09
21. Jung U, Choi MS. Obesity and Its Metabolic Complications: The Role of Adipokines and the Relationship between Obesity, Inflammation, Insulin Resistance, Dyslipidemia and Nonalcoholic Fatty Liver Disease. *Int J Mol Sci*. 2014;15(4):6184-6223.
doi: 10.3390/ijms15046184
22. Sardu C, Santulli G, D' Onofrio N. Editorial: Influence of lifestyle factors in the management of diabetes mellitus. *Front Endocrinol*. 2023;14.
doi: 10.3389/fendo.2023.1258766
23. Eichelmann F, Prada M, Sellem L, et al. Lipidome changes due to improved dietary fat quality inform cardiometabolic risk reduction and precision nutrition. *Nat Med*. 2024;30(10):2867-2877.
doi: 10.1038/s41591-024-03124-1
24. National Department of Health SA. *Review of the National Strategy for the Prevention and Control of Obesity in South Africa (2015-2020)*. Pretoria, South Africa: NDoH; 2020.
25. Nwosu E, Fismen AS, Helleve A, et al. Trends in prevalence of overweight and obesity among South African and European adolescents: a comparative outlook. *BMC Public Health*. 2022;22(1):2287.
doi: 10.1186/s12889-022-14724-2
26. Sifunda S, Mbewu AD, Mabaso M, et al. Prevalence and Psychosocial Correlates of Diabetes Mellitus in South Africa: Results from the South African National Health and Nutrition Examination Survey (SANHANES-1). *Int J Environ Res Public Health*. 2023;20(10):5798.
doi: 10.3390/ijerph20105798
27. Owolabi EO, Goon DT, Ajayi AI, Adeniyi O V, Chu KM. Coverage of diabetes complications screening in rural Eastern Cape, South Africa: A cross-sectional survey. *South Afr Fam Pract*. 2022;64(1).
doi: 10.4102/safp.v64i1.5447
28. Raal FJ, Blom DJ, Naidoo S, Bramlage P, Brudi P. Prevalence of dyslipidaemia in statin-treated patients in South Africa : results of the DYSLipidaemia International Study (DYSIS). *Cardiovasc J Afr*. 2013;24(8):330-338.
doi: 10.5830/CVJA-2013-071
29. Klug E, Raal FJ, Marais AD, et al. South African Dyslipidaemia Guideline Consensus Statement 2018 Update: A joint statement from the South African Heart Association (SA Heart) and the Lipid and Atherosclerosis Society of Southern Africa (LASSA). *S Afr Med J*. 2018;108(11b):973-1000.
doi: 10.7196/samj.2018.v108i11.13383
30. Butalia S, Chen G, Duan Q, Anderson TJ. Care gaps in achieving cholesterol targets in people with diabetes: A population-based study in a universal health care setting. *Diabetes Res Clin Pract*. 2022;184:109177.
doi: 10.1016/j.diabres.2021.109177
31. Addis Z, Nega AT, Tebeje RD, et al. Dyslipidemia and associated factors among adult type two diabetes mellitus patients in Felege Hiywot Refral, Hospital, Bahir Dar, Ethiopia, 2023. *Front Cardiovasc Med*. 2024;11.
doi: 10.3389/fcvm.2024.1493447
32. Reiger S, Jardim TV, Abrahams-Gessel S, et al. Awareness, treatment, and control of dyslipidemia in rural South Africa: The HAALSI (Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa) study. *PLoS ONE*. 2017;12(10):e0187347.
doi: 10.1371/journal.pone.0187347
33. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA

- Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *PLoS Med.* 2009;6(7):e1000100.
doi: 10.1371/journal.pmed.1000100
34. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data. *Int J Evid Based Healthc.* 2015;13(3):147-153.
doi: 10.1097/XEB.0000000000000054
 35. Vezi ZB, Naidoo DP. Dyslipidemia among Black patients with Type 2 Diabetes. *Cardiovasc J South Afr.* 2005;16:194-198.
 36. Ramjeeth A, Butkow N, Raal FJ, Maholwana-Mokgathe M. The evaluation of low-density lipoprotein cholesterol goals achieved in patients with established cardiovascular disease and/or hyperlipidaemia receiving lipid-lowering therapy: the South African Not at Goal study (SA-NAG). *Cardiovasc J Afr.* 2008;19(2):88-94.
 37. Kalk WJ, Joffe BI. The Metabolic Syndrome, Insulin Resistance, and Its Surrogates in African and White Subjects with Type 2 Diabetes in South Africa. *Metab Syndr Relat Disord.* 2008;6(4):247-255.
doi: 10.1089/met.2008.0003
 38. Naidoo S, Raal F. Pattern of dyslipidaemia in relation to statin use in patients with type 2 diabetes mellitus attending a tertiary care hospital. *J Endocrinol Metab Diabetes South Afr.* 2020;25(1):6-11.
doi: 10.1080/16089677.2019.1686869
 39. Mashele TS, Mogale MA, Towobola OA, Moshesh MF. Central obesity is an independent risk factor of poor glycaemic control at Dr George Mukhari Academic Hospital. *South Afr Fam Pract.* 2019;61(1):18-23.
doi: 10.1080/20786190.2018.1527134
 40. Moshane P.T, Mogale M.A, Adu A, Towobola O.A. Prevalence, Patterns, and Management of Diabetic Dyslipidemia among Black South African Patients with Type 2 Diabetes at a South African Semi-Urban Tertiary Hospital. *SCIREA J Clin Med.* 2020;5(6):144-159.
 41. Williams KH, Shackel NA, Gorrell MD, McLennan S V., Twigg SM. Diabetes and Nonalcoholic Fatty Liver Disease: A Pathogenic Duo. *Endocr Rev.* 2013;34(1):84-129.
doi: 10.1210/er.2012-1009
 42. Nogueira JP, Cusi K. Role of Insulin Resistance in the Development of Nonalcoholic Fatty Liver Disease in People With Type 2 Diabetes: From Bench to Patient Care. *Diabetes Spectr.* 2024;37(1):20-28.
doi: 10.2337/dsi23-0013
 43. Mitrovic B, Obradovic M, Gluvic Z, *et al.* Non-alcoholic Fatty Liver Disease, Metabolic syndrome, and Type 2 diabetes mellitus: Where do we stand today? *Arch Med Sci.* Published online June 3, 2022.
doi: 10.5114/aoms/150639
 44. Wang Z, Chen J, Zhu L, Jiao S, Chen Y, Sun Y. Metabolic disorders and risk of cardiovascular diseases: a two-sample mendelian randomization study. *BMC Cardiovasc Disord.* 2023;23(1):529.
doi: 10.1186/s12872-023-03567-3
 45. Hirano T. Pathophysiology of Diabetic Dyslipidemia. *J Atheroscler Thromb.* 2018;25(9):771-782.
doi: 10.5551/jat.RV17023
 46. Hyassat D, Al-Saeksaek S, Naji D, *et al.* Dyslipidemia among patients with type 2 diabetes in Jordan: Prevalence, pattern, and associated factors. *Front Public Health.* 2022;10.
doi: 10.3389/fpubh.2022.1002466
 47. Salama II, Sami SM, Salama SI, *et al.* Impact of Lifestyle Modification on Glycemic Control and Cognitive Function Among Type II Diabetes Mellitus Patients. *Future Sci OA.* 2023;9(1).
doi: 10.2144/fsoa-2022-0060
 48. Reichley R, McKinnon PS, Seaton T, Noirot L, Dunagan WC, Bailey TC. Adherence to dyslipidemia treatment guidelines in diabetic patients. *AMIA Annu Symp Proc.* 2006;2006:1071.
 49. Ntsekhe M, Fourie JM, Scholtz W, Scarlatescu O, Nel G, Sliwa K. South Africa Country Report PASCAR and WHF Cardiovascular Diseases Scorecard project. *Cardiovasc J Afr.* 2021;32(1):49-58.
doi: 10.5830/CVJA-2021-002
 50. Brennan AT, Kileel EM, Fox MP, *et al.* Assessing compliance with national guidelines in diabetes care: A study leveraging data from south Africa's National Health Laboratory Service (NHLS). *PLoS Global Public Health.* 2024;4(9):e0003014.
doi: 10.1371/journal.pgph.0003014
 51. Grundlingh N, Zewotir TT, Roberts DJ, Manda S. Assessment of prevalence and risk factors of diabetes and pre-diabetes in South Africa. *J Health Popul Nutr.* 2022;41(1):7.
doi: 10.1186/s41043-022-00281-2
 52. Ntusi N. Dyslipidaemia in South Africa. *South Afr Med J.* 2018;108(4):256.
doi: 10.7196/SAMJ.2018.v108i4.13265
 53. Chiveto D, Musarurwa C, Mapira H, *et al.* Glycemic Control and Cardiometabolic Risk in Black Zimbabweans with Type 2 Diabetes Mellitus. *Diabetes Metab Syndr Obes.* 2024;Volume 17:3187-3196.
doi: 10.2147/DMSO.S473042

54. Kiplagat SV, Lydia K, Jemimah K, Drusilla M. Prevalence of Dyslipidemia and The Associated Factors Among Type 2 Diabetes Patients in Turbo Sub-County Kenya. *J Endocrinol Diabetes*. 2017;4(5):1-9.
doi: 10.15226/2374-6890/4/5/00190
55. Oguejiofor O, Onwukwe C, Odenigbo C. Dyslipidemia in Nigeria: Prevalence and pattern. *Ann Afr Med*. 2012;11(4):197.
doi: 10.4103/1596-3519.102846
56. Alici G, Genç Ö. The pattern of dyslipidemia among Somali type 2 diabetic patients: a cross-sectional study. *Eur J Med Res*. 2022;27(1):253.
doi: 10.1186/s40001-022-00882-x
57. Boadu WIO, Anto EO, Frimpong J, et al. Prevalence, knowledge, and lifestyle-associated risk factors of dyslipidemia among Ghanaian type-2 diabetes mellitus patients in rural and urban areas: A multicenter cross-sectional study. *Health Sci Rep*. 2023;6(8).
doi: 10.1002/hsr2.1475
58. Katundu KGH, Mukhula V, Phiri T, et al. High prevalence of dyslipidaemia among persons with diabetes mellitus and hypertension at a tertiary hospital in Blantyre, Malawi. *BMC Cardiovasc Disord*. 2022;22(1):557.
doi: 10.1186/s12872-022-03011-y
59. Gao H, Wang H, Shan G, et al. Prevalence of dyslipidemia and associated risk factors among adult residents of Shennu City, China. *PLoS ONE*. 2021;16(5):e0250573.
doi: 10.1371/journal.pone.0250573
60. Gu D, Wang D, Zhu Q, Luo L, Zhang T. Prevalence of dyslipidemia and associated factors in sedentary occupational population from Shanghai: a cross-sectional study. *Arch Public Health*. 2024;82(1):21.
doi: 10.1186/s13690-024-01245-0
61. Tóth PP, Potter D, Ming EE. Prevalence of lipid abnormalities in the United States: The National Health and Nutrition Examination Survey 2003–2006. *J Clin Lipidol*. 2012;6(4):325-330.
doi: 10.1016/j.jacl.2012.05.002
62. Afroz A, Ali L, Karim MdN, et al. Glycaemic Control for People with Type 2 Diabetes Mellitus in Bangladesh - An urgent need for optimization of management plan. *Sci Rep*. 2019;9(1):10248.
doi: 10.1038/s41598-019-46766-9
63. Tai SY, He JS, Kuo CT, Kawachi I. Urban–Rural Disparities in the Incidence of Diabetes-Related Complications in Taiwan: A Propensity Score Matching Analysis. *J Clin Med*. 2020;9(9):3012.
doi: 10.3390/jcm9093012
64. Gassasse Z, Smith D, Finer S, Gallo V. Association between urbanisation and type 2 diabetes: an ecological study. *BMJ Glob Health*. 2017;2(4):e000473.
doi: 10.1136/bmjgh-2017-000473
65. Ghosh S, Paul M, Mondal KK, Bhattacharjee S, Bhattacharjee P. Sedentary lifestyle with increased risk of obesity in urban adult academic professionals: an epidemiological study in West Bengal, India. *Sci Rep*. 2023;13(1):4895.
doi: 10.1038/s41598-023-31977-y
66. Han KT, Kim S. Regional Prevalence of Dyslipidemia, Healthcare Utilization, and Cardiovascular Disease Risk in South Korean: A Retrospective Cohort Study. *Int J Environ Res Public Health*. 2021;18(2):538.
doi: 10.3390/ijerph18020538
67. Ali N, Kathak RR, Fariha KA, Taher A, Islam F. Prevalence of dyslipidemia and its associated factors among university academic staff and students in Bangladesh. *BMC Cardiovasc Disord*. 2023;23(1):366.
doi: 10.1186/s12872-023-03399-1
68. Joffe BI, Distiller LA, Kalk WJ. Lipid Levels in Black South Africans With Type 2 Diabetes. *Diabetes Care*. 2004;27(7):1839-1840.
doi: 10.2337/diacare.27.7.1839
69. Ozder A. Lipid profile abnormalities seen in T2DM patients in primary healthcare in Turkey: a cross-sectional study. *Lipids Health Dis*. 2014;13(1):183.
doi: 10.1186/1476-511X-13-183
70. Pokharel DR, Khadka D, Sigdel M, et al. Prevalence and pattern of dyslipidemia in Nepalese individuals with type 2 diabetes. *BMC Res Notes*. 2017;10(1):146.
doi: 10.1186/s13104-017-2465-4
71. Chiesa ST, Charakida M. High-Density Lipoprotein Function and Dysfunction in Health and Disease. *Cardiovasc Drugs Ther*. 2019;33(2):207-219.
doi: 10.1007/s10557-018-06846-w
72. Viece PRN, da Silva B, Hirsch GE, et al. Triglycerides Revisited to the Serial. In: *Advances in Clinical Chemistry*. Elsevier; 2017:1-44.
doi: 10.1016/bs.acc.2016.11.001
73. Alloubani A, Nimer R, Samara R. Relationship between Hyperlipidemia, Cardiovascular Disease and Stroke: A Systematic Review. *Curr Cardiol Rev*. 2021;17(6).
doi: 10.2174/1573403X16999201210200342
74. Peters SAE, Singhathe Y, Mackay D, Huxley RR, Woodward M. Total cholesterol as a risk factor for coronary heart disease and stroke in women compared with men: A systematic review and meta-analysis. *Atherosclerosis*. 2016;248:123-131.

- doi: 10.1016/j.atherosclerosis.2016.03.016
75. Jung E, Kong SY, Ro YS, Ryu HH, Shin SD. Serum Cholesterol Levels and Risk of Cardiovascular Death: A Systematic Review and a Dose-Response Meta-Analysis of Prospective Cohort Studies. *Int J Environ Res Public Health*. 2022;19(14):8272.
doi: 10.3390/ijerph19148272
76. Ravnskov U, de Lorgeril M, Diamond DM, *et al*. LDL-C does not cause cardiovascular disease: a comprehensive review of the current literature. *Expert Rev Clin Pharmacol*. 2018;11(10):959-970.
doi: 10.1080/17512433.2018.1519391
77. Yudin R, Aman AM, Rasyid H, *et al*. Risk of Dyslipidemia in Obese Young Adult Subjects as Measured by Various Obesity Indices. *J Endocrinol Metab*. 2022;12(3):102-106.
doi: 10.14740/jem819
78. Mishra S, Murry B, Devi NK, Tripathi S, Suokhrie S. Obesity in dyslipidemia and hypertension: A study among young adults of Delhi/NCR. *Clin Epidemiol Glob Health*. 2023;22:101335.
doi: 10.1016/j.cegh.2023.101335
79. Zheng C, Liu Y, Xu C, *et al*. Association between obesity and the prevalence of dyslipidemia in middle-aged and older people: an observational study. *Sci Rep*. 2024;14(1):11974.
doi: 10.1038/s41598-024-62892-5
80. Di Pino A, DeFronzo RA. Insulin Resistance and Atherosclerosis: Implications for Insulin-Sensitizing Agents. *Endocr Rev*. 2019;40(6):1447-1467.
doi: 10.1210/er.2018-00141
81. Zhang L, Qiao Q, Tuomilehto J, *et al*. Distinct Ethnic Differences in Lipid Profiles across Glucose Categories. *J Clin Endocrinol Metab*. 2010;95(4):1793-1801.
doi: 10.1210/jc.2009-2348
82. Bentley AR, Rotimi CN. Interethnic variation in lipid profiles: implications for underidentification of African-Americans at risk for metabolic disorders. *Expert Rev Endocrinol Metab*. 2012;7(6):659-667.
doi: 10.1586/eem.12.55
83. Meshkini M, Alaei-Shahmiri F, Mamotte C, Earnest J. Ethnic Variation in Lipid Profile and Its Associations with Body Composition and Diet: Differences Between Iranians, Indians and Caucasians Living in Australia. *J Immigr Minor Health*. 2017;19(1):67-73.
doi: 10.1007/s10903-015-0320-z
84. Cho SMJ, Lee HJ, Shim JS, Song BM, Kim HC. Associations between age and dyslipidemia are differed by education level: The Cardiovascular and Metabolic Diseases Etiology Research Center (CMERC) cohort. *Lipids Health Dis*. 2020;19(1):12.
doi: 10.1186/s12944-020-1189-y
85. Wang Y, Liu X, Dong X, *et al*. Gender-specific relationship between frequency of food-away-from-home with serum lipid levels and dyslipidemia in chinese rural adults. *Lipids Health Dis*. 2022;21(1):112.
doi: 10.1186/s12944-022-01719-6
86. Pan L, Yang Z, Wu Y, *et al*. The prevalence, awareness, treatment and control of dyslipidemia among adults in China. *Atherosclerosis*. 2016;248:2-9.
doi: 10.1016/j.atherosclerosis.2016.02.006