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Atherogenicity of Diabetic Rats Administered Single and Combinatorial Herbal Extracts

Abdullah Ahmad Bilgasem Algarni[1], Yasser Salem Rajah Albaledi[2], Khaled Msfer M Algamdi[3], Adel Mutair Musne Alsulami[4], Zaid Azzam Al Sulami[5], Mohamed Bashah Alsuhaymi[6], Ahmed Saud Samran Althagafi[7], Abdulaziz Yahya Baroji Al-Zubaidi[8], Abdulrahman Fawaz Nasser Alghamdi[9], Ayat Essam Shaaban[10]

[1]Pharmacy Technician / Health surveillance Centers at King Abdulaziz Airport
[2]Nursing Technician / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[3]Radiology Technician / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[4]Nursing Technician / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[5]Nursing Technician / Health surveillance Centers at King Abdulaziz Airport, Jedda
[6]Nursing Specialist / Health surveillance Centers at King Abdulaziz Airport
[7]Nursing Technician / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[8]Nursing Technician / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[9]Emergency Medicine / Health surveillance Centers at King Abdulaziz Airport, Jeddah
[10]Resident Doctor / Al-Naeem Health Center

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ABSTRACT
Background: Diabetes mellitus (DM) is an endocrine condition largely defined as inadequate action or secretion of endogenous insulin, resulting in chronic metabolic syndromes.
Aim: To evaluate atherogenicity of diabetic mice after administration of combinatorial and single herbal extracts.
Materials and methods: The search has been conducted in the following databases: Web of Science, MEDLINE (PubMed), & the Cochrane Library. The trial quality has been assessed utilizing the Cochrane Risk of Bias evaluation instrument one (ROB 1), which is specifically tailored for interventional trials. This evaluation tool includes various factors, including performance bias, selection bias, attrition bias, reporting bias, detection bias, & possible sources of bias. Each experiment has been examined for bias, with researchers classifying the degree of bias as "high," "low," or "unclear" for each evaluated parameter.
Main finding: The linear regression study of the atherogenic index of plasma (AIP) against serum levels of LDL-C in the experimental mice groups yielded a closely fitted regression line ($R^2 = 0.8275$). The atherogenic protection in herbal extract-managed diabetic rats groups ranged from 33.4 to 81.7 percent.
Conclusion: We determined that herbal extracts markedly decreased TG, TC, VLDL-C, & LDL-C levels, while elevating HDL-C as well as enhancing atherogenic risk indices, suggesting their potential as a therapeutic agent for diabetes treatment.

Keywords: Atherogenicity, Diabetic rats, Herbal extracts

INTRODUCTION

DM is an endocrine condition predominantly defined by inadequate action or secretion of endogenous insulin, resulting in chronic metabolic syndromes. The etiologic categorization of diabetes mellitus is predicated on deficiencies in insulin production (Insulin-Dependent Diabetes Mellitus; IDDM or Type one diabetes mellitus) & resistance of peripheral tissues to insulin action (Non-Insulin-Dependent Diabetes Mellitus; Type two diabetes mellitus or NIDDM (**1**).
Atherogenesis refers to the processes within vascular tissues, driven by acellular and cellular components, that lead to the development of atheromatous plaque on the artery inner walls. The development of atheromatous plaque results in the constriction of flow of blood pathways and the hardening of arterial walls (atherosclerosis), ultimately leading to the manifestation of cardiovascular diseases (CVD) **(2)**.
The lipid profile delineates the proportional content of lipids in the blood. The assessment of blood particle complex lipid levels & their ratios provides dependable diagnostic and prognostic information for atherogenic dyslipidemia, determining the risk of arteriosclerosis, and anticipating cardiovascular mortality and morbidity. Increased serum triacylglycerol (TAG), total cholesterol (TC), LDL-C, & VLDL-C levels over their reference

ranges frequently signify dyslipidemia and a heightened risk of cardiovascular disease (CVD). Increased serum LDL-C & TAG levels are significant contributors to the heightened incidence of cardiovascular events **(3)**.
Medicinal plants give alternative and significant medicinal ingredients for the treatment of disorders and illnesses. The primary phytochemical ingredients of Anderson and Asystasiagangetica. L. T. Acanthus montanus (Nees) T. Anderson, Gongronemalatifolium Benth, &Solanum melongena L. var. inerme D.C. Hiern were documented by multiple authors. Furthermore, the nutraceutical attributes of A. montanus, A. gangetica, S. melongena, & G. latifolium were documented in other studies **(4, 5)**.
The efficient management of hyperglycaemia with natural antioxidants could be crucial in mitigating DM consequences, particularly macro - & micro -vascular disorders. Plants utilized in conventional medicine for diabetes treatment constitute a significant substitute for managing the condition, owing to their affordability, efficacy, & few side effects. Consequently, caffeic a`, found in propolis from honeybee hives, various fruits, vegetables, & beverages including tomatoes, carrots, blueberries, strawberries, coffee, olive oil, potatoes, artichokes, pears, chicory, kiwis, cherries, apples, and plums—exhibits an extensive range of pharmacological activities **(6)**.
Dietary polyphenols, such as caffeic a`, may impede β-glucosidase & α-amylase activity, hinder absorption of glucose in the gut via sodium-dependent glucose transporter 1, promote secretion of insulin, & diminish glucose production by liver. Polyphenols may boost insulin-dependent absorption of glucose, stimulate adenosine monophosphate-activated protein kinase, alter the microbiota, & exhibit anti-inflammatory, antibacterial, antioxidant, antidiabetic, immunomodulatory, hypocholesterolemic, & anti-aging properties **(7)**.
This meta-analysis and systematic review assessed the atherogenicity in mice with diabetes following the administration of each and combined herbal extracts.

Subjects and methods
This systematic review has been conducted in agreement with the criteria outlined in the Cochrane Handbook for systematic reviews of interventions & the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.
PICOs: A particular inquiry has been formulated utilizing the Intervention, Population, Comparison, and Outcomes (PICOs) framework. The PICOs questions have been delineated as follows: Population (P): Diabetic rats; Intervention (I): Single and combined herbal extracts; Comparison (C): Conventional treatment; Outcome (O): Atherogenicity of materials from diabetic rats; Research design: In vitro and in vivo investigations. This systematic review has been founded on the subsequent inquiry: Do single and combinatorial herbal extracts influence the atherogenicity in mice with diabetes?
Search Strategy: The research has been conducted in the following databases: Web of Science, MEDLINE (PubMed), & the Cochrane Library.
Eligibility criteria: Research that satisfied the following inclusion criteria have been incorporated: (a) in vitro and in vivo research; (b) investigations examining diabetic mice; and (c) research assessing the impact of single and combined herbal extracts on the atherogenicity of mice with diabetes. Research that fulfilled one or more of the following criteria had been excluded: (a) research that doesn't utilize single or combinatorial herbal extracts; (b) reviews, methods, or guidelines; and (c) obsolete research. Evaluation and selection Data extraction has been conducted separately and in duplicate by two reviewers utilizing a standardized form in Microsoft Excel.
Data extraction: The subsequent data have been obtained from the whole texts of the involved articles: authorship and intervention, year of publication, sample size, & the design of the study.

Methods
GLIDE (Schrodinger, LLC, New York, 2019-2) and Maestro-Desmond Interoperability Tools, version 4.1 (Schrodinger, New York, 2015) have been utilized to carry out docking and molecular dynamics investigations, correspondingly. The in vitro inhibitory actions of chlorogenic a` on α-amylase & α-glucosidase have been assessed. Biochemical experiments have been conducted utilizing standard kits. A solitary intra-peritoneal (i.p.) injection of ninety milligrams per kilogram body weight of alloxan monohydrate has been administered to the mice to stimulate diabetic mellitus. Profiles of serum lipid have been assessed via standard spectrophotometric techniques, whereas atherogenicity, ratios of lipid in blood, & atherogenic coefficients/indices have been computed utilizing established formulas.

Risk of bias evaluation
The research quality has been evaluated utilizing the Cochrane Risk of Bias evaluation instrument one (ROB 1), which is specifically intended for interventional research. This evaluation tool includes various factors, including performance bias, selection bias, attrition bias, detection bias, reporting bias, & possible sources of bias. Each trial has bee evaluated for bias, with researchers classifying the degree of bias as "high," "low," or "unclear" for each measured variable.

Data synthesis

We performed a single-arm meta-analysis aggregating the mean changes (MCs) for our continuously evaluated outcomes together with their respective ninety-five percent confidence interval (CIs). The fixed effect model has been utilized when the effect estimate has been aggregated from homogenous research; otherwise, the random effect model had been used. We examined statistical heterogeneity among research utilizing the I2 statistics Chi2-P test, with Chi2-p > 0.1 indicating heterogeneity, and I2 ≥50% suggesting significant heterogeneity. All statistical analyses have been conducted using Open-Meta Analyst software.

RESULTS

Literature search results

During our preliminary examination of databases, we discovered 650 investigations. After eliminating duplicate research, 335 remained for further assessment. The screening method incorporated titles and abstracts, resulting in the identification of thirty-five papers deemed potentially relevant, which will undergo thorough full-text evaluation. Subsequently, thirty-two investigations have been excluded. Ultimately, 3 research conformed to the specified inclusion criteria. The PRISMA flowchart in **Figure 1** illustrates the representation of this selection process.

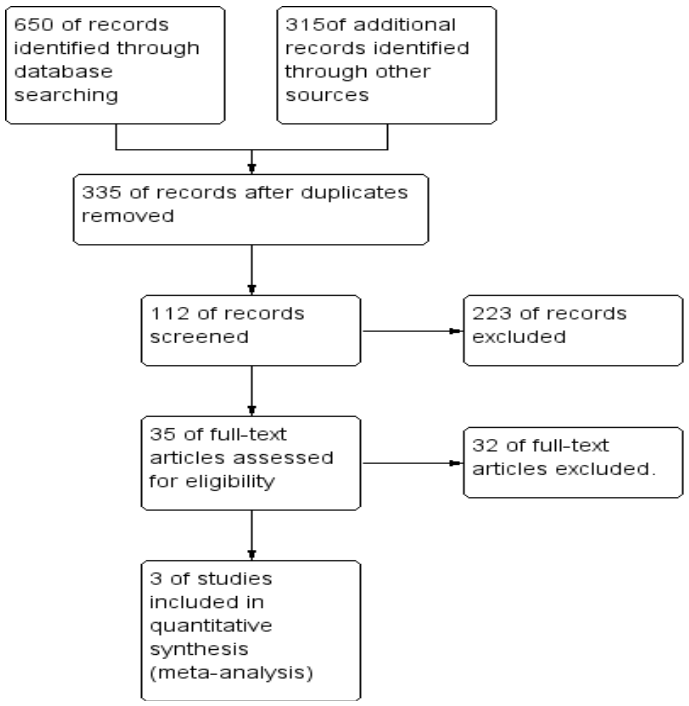


Figure 1. PRISMA flow diagram presented study selection process.

Table 1: Shows characteristics of the involved investigations.

Study ID	Study design	Site	Sample Size	Intervention
Chikezie et al, (8)	clinical trial	Nigera	102	
Group 1			6	Normal mice have one milliliter per kilogram of B.W of phosphate-buffered saline.
Group 2			6	DM-r have one milliliter per kilogram of B.W of phosphate buffer saline
Group 3			6	DM-r had single herbal formulations; A. montanus (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 4			6	DM-r had single herbal formulations; A. gangetica (two hundred milligrams per kilogram in phosphate buffer saline; intraperitoneal.).
Group 5			6	DM-r had single herbal formulations; G. latifolium (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 6			6	DM-r had single herbal formulations; S. melongena (two hundred

				milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.)
Group 7			6	DM-r had double herbal formulations; (ratio: one: one w/w) of A. montanus + A. gangetica (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal).
Group 8			6	DM-r had double herbal formulations; (ratio: one: one w/w) of G. latifolium + A. gangetica (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.)
Group 9			6	DM-r had double herbal formulations; (ratio: one: one w/w) of S. melongena + A. gangetica (two hundred milligrams per kilogram B.W in phosphate buffer saline; i.p.).
Group 10			6	DM-r had double herbal formulations; (ratio: one: one w/w) of G. latifolium + A. montanus (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal).
Group 11			6	DM-r had double herbal formulations; (ratio: one: one w/w) of S. melongena + A. montanus (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 12			6	DM-r had double herbal formulations; (ratio: one: one w/w) of S. melongena + G. latifolium (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 13			6	DM-r had triple herbal formulations; (ratio: 1:1:1 w/w) of G. latifolium + A. gangetica + S. melongena (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 14			6	DM-r had triple herbal formulations; (ratio: 1:1:1 w/w) of A. gangetica + A. montanus + G. latifolium (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 15			6	DM-r had triple herbal formulations; (ratio: 1:1:1 w/w) of A. gangetica + A. montanus + S. melongena (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 16			6	DM-r had triple herbal formulations; (ratio: 1:1:1 w/w) of S. melongena + A. montanus + G. latifolium (two hundred milligrams per kilogram B.W in phosphate buffer saline; intraperitoneal.).
Group 17			6	DM-r had quadruple herbal formulation; (ratio: 1:1:1:1 w/w) of G. latifolium + A. gangetica + A. montanus + S. melongena (two hundred milligrams per kilogram B.W in PBS; intraperitoneal.).
Orsolic et al, (9)	clinical trial	Croatia	60	
Group 1			15	control animals (healthy normal specimens) administered fifty milliliters of distilled water intraperitoneally everyday for 7 days:
Group 2			15	Normal, healthy animals were administered with caffeic a` (CA), which has been dissolved in H2O & subsequently injected i.p into rats.
Group 3			15	The diabetic control group administered an intravenous injection of alloxan at a single dosage of seventy five mg kg−1, serving as the untreated diabetic group.
Group 4			15	Diabetic group administered caffeic a` (fifty mg kg−1 intraperitoneal every day) for 7 days, commencing 2 days post-alloxan injection.
Singh et al, (10)	Invitro study	India	25	
Group 1			5	Normal control: They had citrate buffer (pH- 4.5) intraperitoneal
Group 2			5	Diabetic control: Mice have been administered STZ (fifty milligrams per kilogram body weight).
Group 3			5	Metformin treated: The rats with diabetes received oral metformin (one hundred milligrams per kilogram body weight) diluted in double distilled water (DDW) daily for twenty-eight days.
Group 4			5	chlorogenic a` treated: Rats with diabetes received oral administration of chlorogenic a` (one hundred milligram per kilogram) washed in double distilled water daily for a duration of twenty-eight days.
Group 5			5	chlorogenic a` treated: The rats with diabetes were orally supplied chlorogenic a` (CGA) at a dosage of 150 milligrams per kilogram,

				dissolved in double distilled water, daily for a duration of twenty-eight days.

Risk of bias assessment

Regarding our included studies All domains shows low risk of bias except for detection bias & reporting bias showed high risk, Risk of bias assessment summary and graph were presented in figure 2 and table 2.

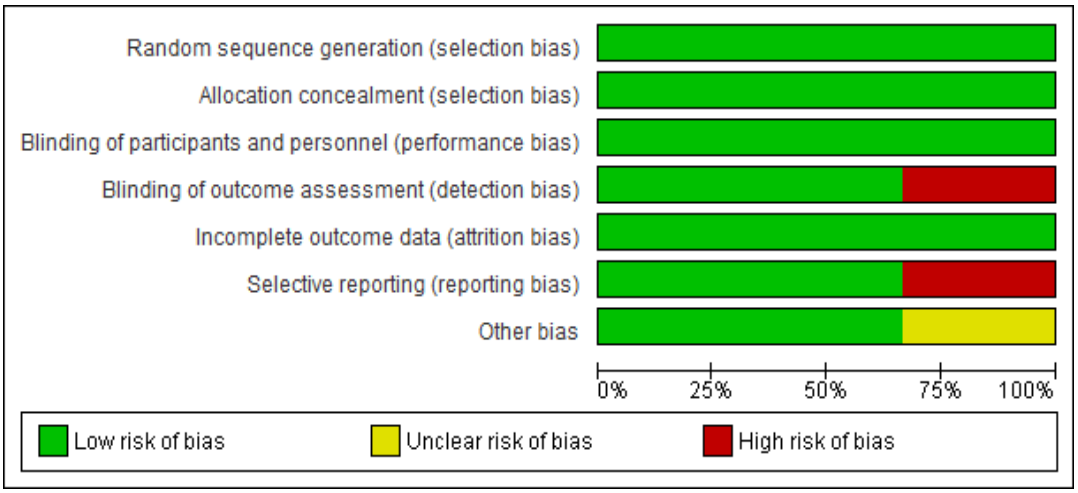
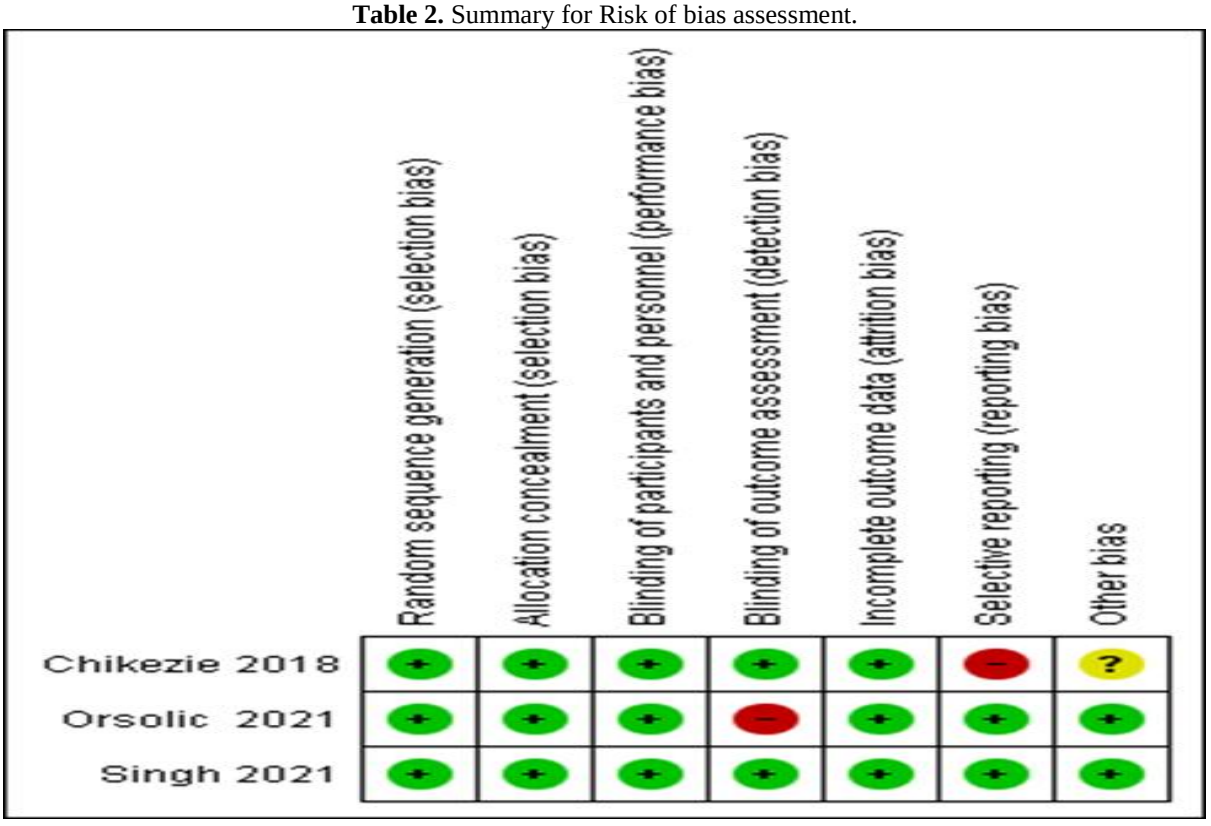


Figure 2. Risk of bias assessment graph.

Table 2. Summary for Risk of bias assessment.



Outcomes

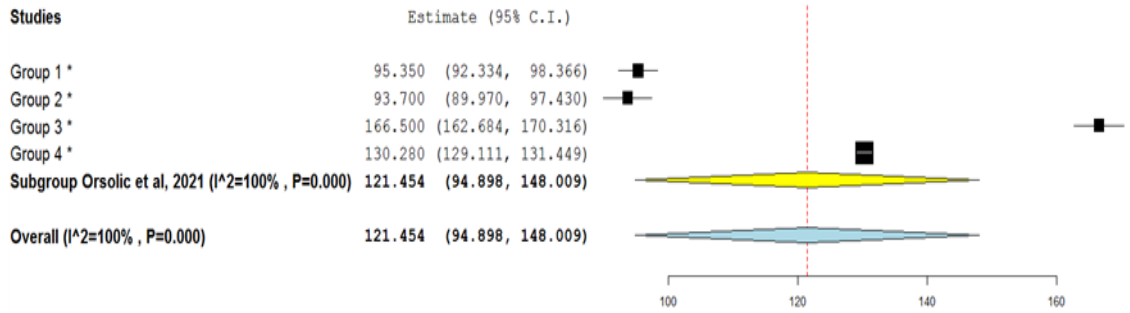


Figure 3. Forest plot for TC**.**

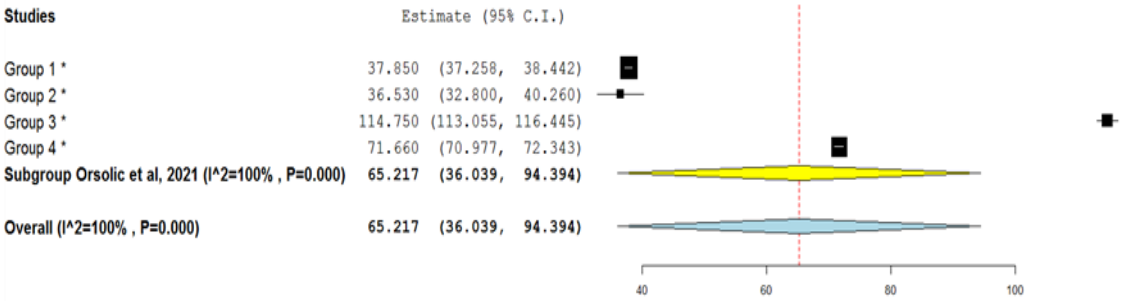


Figure 4. Forest plot for LDL –C**.**

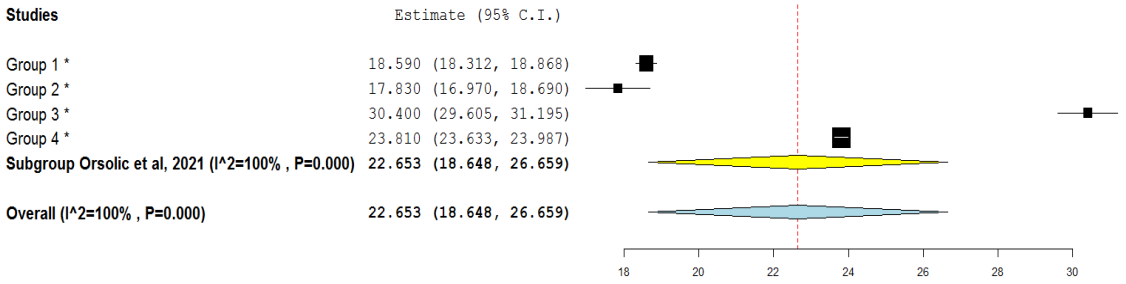


Figure 5. Forest plot for VLDL-C.

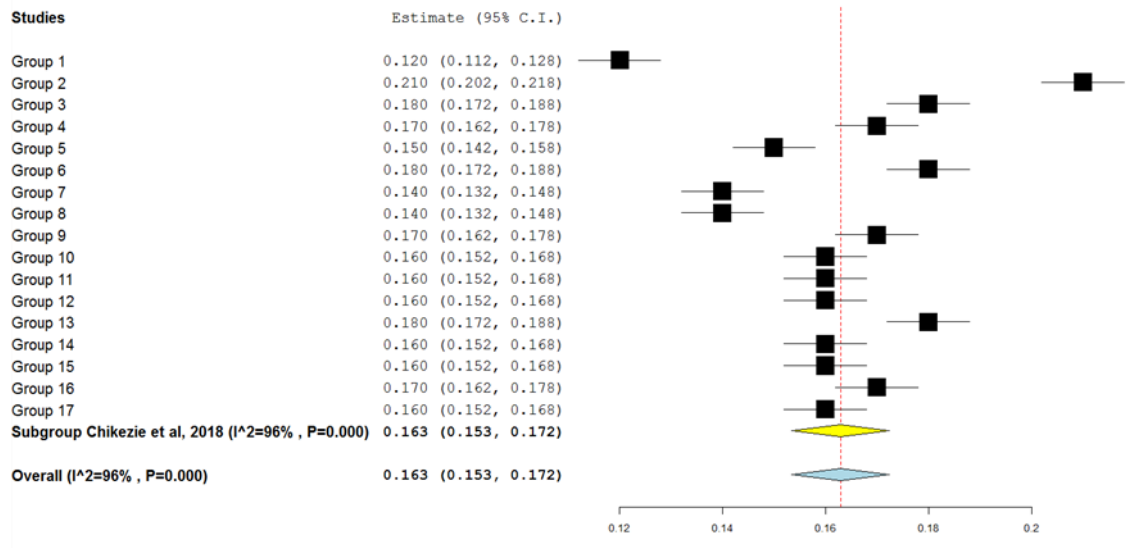


Figure 6. The forest plot for triglycerides

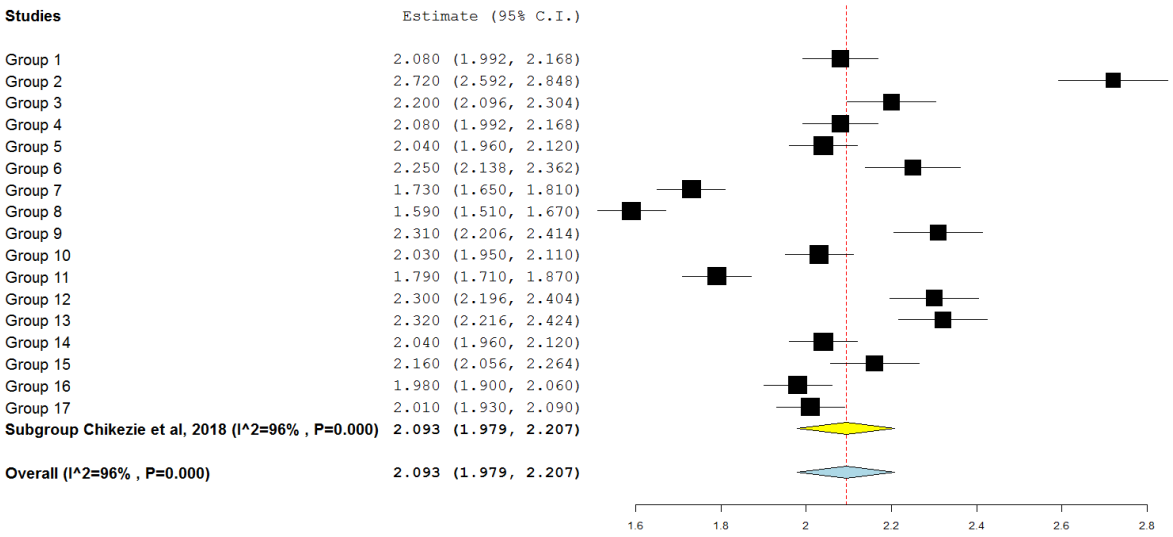


Figure 7. Represents the forest plot for total cholesterol.

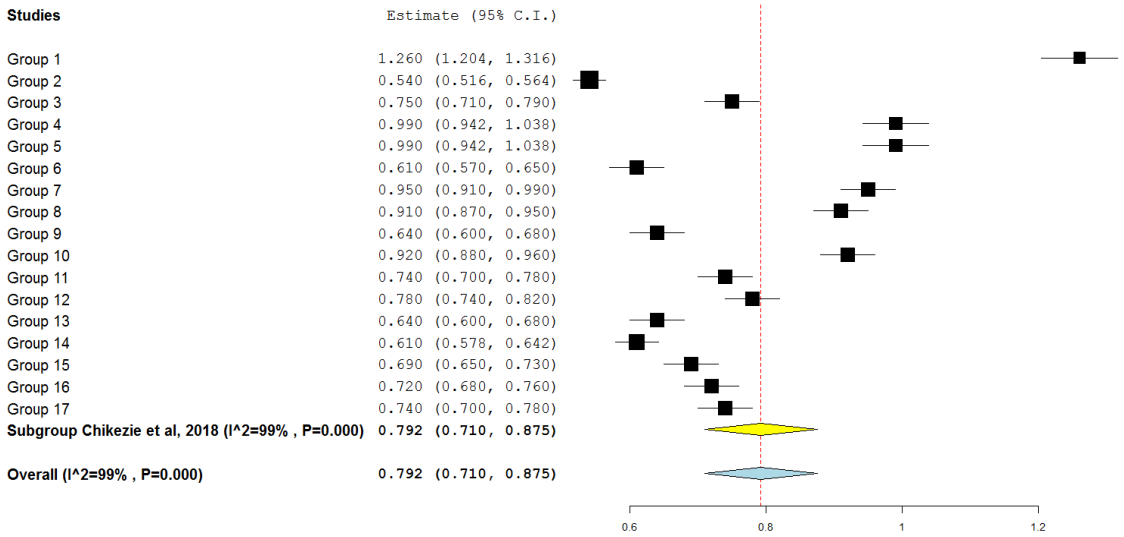


Figure 8. Represents the forest plot for HDL C.

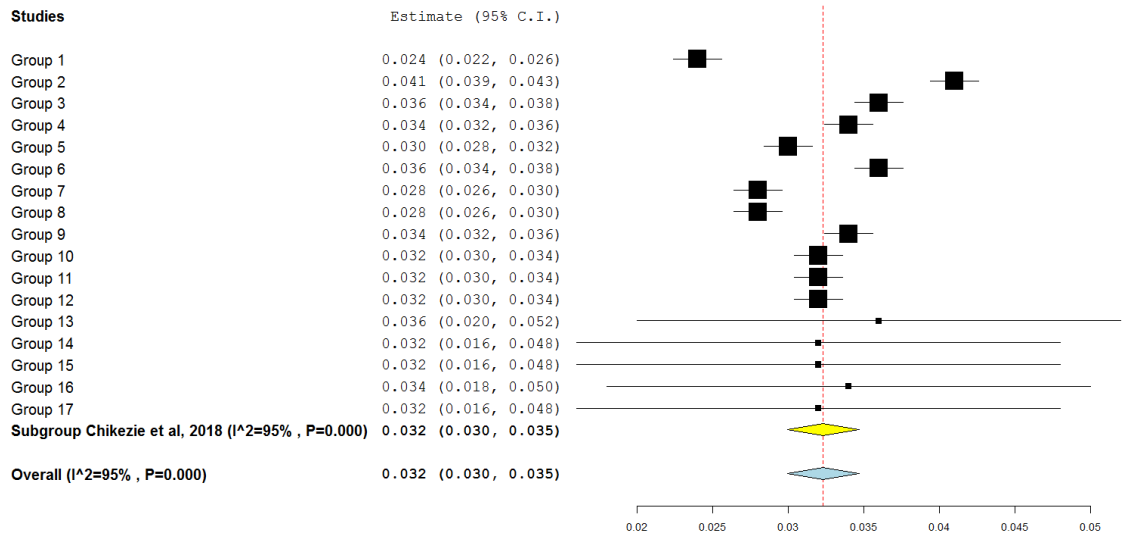


Figure 9. Represents the forest plot for LDL C.

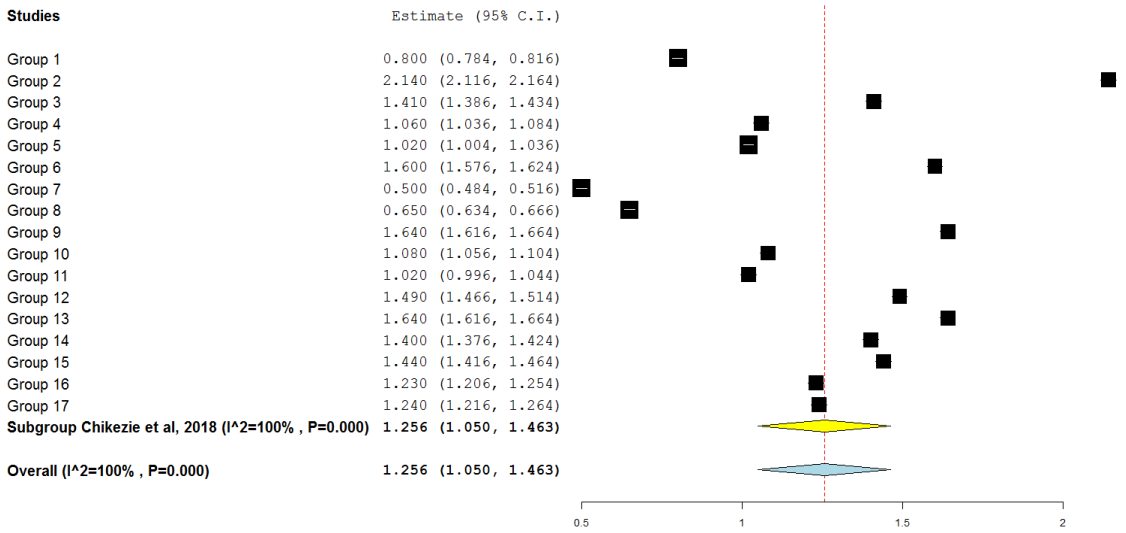


Figure 10. Represents the forest plot for VLDL C.

DISCUSSION

DM is a metabolic condition that has become an important issue in the 21st century, with its incidence increasing internationally, especially in Africa **(11)**. Diabetes mellitus progressively deteriorates and is associated with significant consequences, notably hyperlipidemia, atherosclerosis, and cardiovascular diseases (CVDs) **(12)**. Diabetic cases exhibit a greater extent of atherosclerotic load attributable to dyslipidemia compared to non-diabetic individuals **(13)**. This encompasses heightened concentrations of total cholesterol and triglycerides, which are significant risk factors contributing to cardiovascular illnesses **(14)**.

Plants serve as natural repositories of medicinal substances, with their stems, roots, seeds, & leaves abundant in flavonoids, polysaccharides, phytosterols, saponins, phenols, polypeptides, fatty acids, & many small molecular entities, which constitute the active ingredients in pharmaceuticals for cardiovascular ailments **(15)**.

The activity of plant extracts is attributed to the presence of polyphenolic chemicals found in various plant sections. Natural phytochemicals are highly promising for treating various illnesses, involving diabetes, because of their little side effects and low cost **(10)**.

The biological activity of polyphenolic derivatives, including procyanidins, quercetin, as well as flavonols, was demonstrated by distinct properties: antiallergic, antioxidant, antiviral, anti-inflammatory, antiproliferative, antimutagenic, anticarcinogenic, & antimicrobial, by inhibiting free radicals, controlling cell cycle arrest, inducing apoptosis, & enhancing antioxidant enzyme activity **(16)**.

This systematic review and meta-analysis encompassed three papers **(10), (9),** and **(8)**.

Outcomes

Singh et al. (10) investigated the impact of chlorogenic acid therapy on lipid profile. The second group of mice had a significant increase (p-value less than 0.001) in blood total cholesterol and triglycerides relative to healthy mice. Nevertheless, TC values have been seen as consistently within the normal range across all groups. In contrast, the high-density lipoprotein cholesterol concentration was significantly (p-value less than 0.001) reduced in second group of mice than the healthy mice.

Metformin and CGA administration decreased triglycerides and total cholesterol levels to approximate control values. Rats treated with Metformin demonstrated a substantial increase in HDL-C levels (p-value less than0.001). CGA administered orally at 150 mg/kg results in a considerable (p-value less than 0.001) enhancement of HDL-C levels. The alteration in HDL-C levels seen in rats administered CGA at 100 mg/kg was statistically insignificant. Hyperglycemia is the primary risk factor for cardiovascular disease in type 1 diabetes.

Mice with diabetes exhibited a substantial elevation (p-value less than 0.01) in blood concentrations of total cholesterol, triglycerides, very low-density lipoprotein-cholesterol, low-density lipoprotein, & atherogenic index values compared to healthy control mice. Conversely, HDL-C significantly diminished has been observed in untreated mice with diabetes, with significant differences observed among untreated mice with diabetes and those managed with CA; CA administration lead to a reduction of concentrations of blood of total cholesterol and triglycerides by about twenty-two percent, & very low-density lipoprotein & low-density lipoprotein-cholesterol by 21.70 & 37.56 percent, correspondingly, while high-density lipoprotein raised by sixty-three

percent in comparison to the diabetic control rats.

Wang et al. (17) examined the inhibitory impact of chlorogenic a` on the development of T2DM utilizing Sprague Dawley (SD) mice, a recognized type to diabetes model produced by a high-fat high-sucrose diet (HFSD) as well as streptozotocin (STZ). They reported a significant reduction in serum total cholesterol, triglycerides, cholesterol & LDL levels in the chlorogenic acid treatment group ($P<0.01$), while serum high-density lipoprotein cholesterol (HDL-C) levels increased ($P<0.05$). Additionally, the diabetes model group exhibited significantly elevated levels of serum TG, HDL-C, TC, and LDL-C compared to healthy controls ($P<0.01$).

Additionally, I concur with **Irondi et al. (18)**, who aimed to quantify the principal flavonoids & phenolic a` of pharmacological significance in seed flour and assessed its anti- diabetic effects in a great-fat diet, small-dose streptozotocin-induced T2DM mice model. They stated that both the seed flour-treated group and the Metformin-treated group exhibited a significant enhancement in HDL-C concentrations compared to the non-treated group (p-value less than 0.05). The diabetic mice exhibited a significant (p-value less than 0.05) elevation in plasma total cholesterol, triglycerides, LDL-C, & very low-density lipoprotein cholesterol, alongside a notable (p-value less than 0.05) reduction in plasma high-density lipoprotein cholesterol relative to the normal control group.

The linear regression study of the AIP against serum concentrations of low-density lipoprotein cholesterol in the experimental mice groups produced a closely fitted regression line ($R^2 = 0.8275$). The atherogenic protection of herbal extract-treated groups of mice with diabetes ranged from 33.4 to 81.7 percent.

Consistent with **Ahmadvand et al. (19),** who aimed to evaluate the potential advantageous impact of caffeic acid (CA) on serum lipid metrics as well as atherogenic index in alloxan-induced male mice with diabetes, it has been reported that the serum levels of TC, low-density lipoprotein-cholesterol, TG, & very low-density lipoprotein-cholesterol in the diabetic control group were significantly elevated than healthy control group. The administration of CA to mice with diabetes significantly reduced TC (21.7 percent), TG (21.64%), and LDL-C (26.65%) than diabetic control group. A substantial drop in blood HDL-C levels has been detected in the diabetes control group than the healthy group. The administration of CA to mice with diabetes significantly elevated their serum HDL-C levels in comparison to the diabetic control group.

Furthermore, it was revealed a significant elevation has observed in the blood concentrations of the atherogenic index (total cholesterol/ high-density lipoprotein cholesterol and low-density lipoprotein-cholesterol / high-density lipoprotein cholesterol) in the diabetic control group relative to the healthy control group. The therapy of diabetic rats significantly reduced the serum concentrations of TC/ HDL-C (24.8%) and LDL-C / HDL-C (30.6%) in comparison to the diabetic control group.

Salem et al. (20) examined the effect of caffeic acid on miR-636 expression levels in the kidneys of diabetic rats infected with streptozotocin, reporting a significant increase (p-value less than 0.001) in blood total cholesterol, triglycerides, & low-density lipoprotein cholesterol in comparison to the control group. Nonetheless, HDL-C exhibited a considerable reduction (p-value less than 0.001) in mice with diabetes relative to the normal control group. Caffeic acid administration resulted in a hypolipidemic effect on the serum lipids of diabetic mice, dramatically reducing the levels of triglycerides (TG), total cholesterol, & low-density lipoprotein cholesterol compared to diabetic mice, but these levels remained significantly elevated relative to controls.

Concerning an investigation by **Chikezie et al. (8)** that compares the seventeen groups: The pooled meta-analysis for triglycerides yielded a mean difference (MD) of 0.16 with a ninety-five percent confidence interval of [0.15, 0.17]. For total cholesterol, the pooled MD was 2.09 with a ninety-five percent confidence interval of [1.97, 2.2]. The analysis for HDL-C resulted in a pooled MD of 0.79 with a ninety-five percent confidence interval of [0.71, 0.87]. For LDL-C, the pooled MD was 0.032 with a ninety-five percent confidence interval of [0.03, 0.035]. Lastly, the pooled MD for VLDL-C was 1.256 with a ninety-five percent confidence interval of [1.05, 1.46].

According to **Ojiako et al. (21)**, who investigated the efficacy of combinatorial & single herbal formulations from the leaf extracts of Hibiscus rosasinensis, Emilia coccinea, Acanthus montanus, &Asystasiagangetica in reversing dyslipidemia & hyperglycemia in alloxan-induced diabetic male mice, it was reported that serum triglyceride levels in diabetic mice administered DHf were significantly lesser than those in the diabetic control group, with the HrAMEC and HrAMHR groups exhibiting markedly reduced levels compared to the control group; p-value less than 0.05. The HrAGEH group was substantially lower than the control group. Nevertheless, the HrAMEH group and the HrAAEH group didn't exhibit a statistically significant difference (p-value more than0.05) compared to the diabetic control group.

The research indicated that diabetics administered SHf exhibited significantly decreased serum total cholesterol (TC) levels than control group. Nonetheless, diabetics administered DHf exhibited insignificant variation in TC levels. Serum TC levels of HrAGEH and HrAMAE were lower than those of the control group, but HrAMAH, HrAMEH, and HrAAEH levels exhibited significant differences than diabetes control group. HDL-C levels weren't statistically different between diabetic groups receiving SHf and control groups, but were elevated in the diabetic treatment groups. LDL-C levels have been elevated in diabetic cohorts receiving SHf and DHf, but

diabetic groups administered SHf exhibited no significant variation. HrAGHR and HrAMEC levels have been diminished compared to both the diabetes control and healthy control groups, however HrAMHR levels have been elevated relative to the diabetic control group.

Chikezie et al. (22) assessed the efficacy of double herbal formulations (DHFs), single herbal formulations (SHFs), quadruple herbal formulations (QHF), & triple herbal formulations (THFs) derived from leaf extracts of Asystasiagangetica, Acanthus montanus, Solanum melongena, &Gongronemalatifolium in reversing dyslipidemia & hyperglycemia in diabetic rats (DM-r). They found that the serum triglyceride concentration in Group 3 was significantly different (p-value less than 0.05) from that of Groups 4, 6, and 9. The serum triglyceride levels in all experimental rat groups were considerably elevated (p-value less than 0.05) compared to Group 1. In contrast, the serum triglyceride concentration in all experimental mice groups was considerably lower (p-value less than 0.05) than that of Group 2.

Our study revealed that blood triglyceride concentrations in different experimental mice groups were significantly reduced than those in Groups two, seven, eight, and eleven. Our findings also indicated that rat groups receiving herbal formulations exhibited comparatively low serum HDL-C values. Serum LDL-C levels exhibited significant variability among the experimental rat groups, with Group 2 displaying the highest concentration and Group 8 the lowest. The rat groups treated with the herbal formulation exhibited significantly elevated LDL-C concentrations compared to Group 1, but the concentrations in the herbal formulation-treated rat groups were lower. Serum VLDL-C levels exhibited a similar trend to serum triglyceride levels, with VLDL-C concentrations being approximately fivefold more than the corresponding triglyceride levels.

Folane et al. (23) aimed to assess the antidiabetic efficacy of a polyherbal formulation comprising Piper nigrum, Citrullus colocynthis, Cinnamomum tamala, and Asparagus racemosus in alloxan-induced diabetic mice. They reported a significant reduction in raised total triglycerides & cholesterol levels in the extract-treated groups compared to the Diabetic Control group, with significant variations observed among these groups and the healthy group.

In the extract-treated groups, there was a significant reduction in total LDL & VLDL levels, accompanied by a rise in HDL levels, compared to the Diabetic Control group, with significant variations observed among these groups & the healthy group.

CONCLUSION

In general, this systemic review and meta-analysis showed a significant reduction in TG, TC, LDL-C, and VLDL-C, with a notable rise in HDL-C levels. These effects were particularly pronounced in herbal extracts treated by groups, suggesting its potential as a therapeutic agent for managing dyslipidemia in diabetic rates. Furthermore, the atherogenic risk indices (ARIs) were significantly improved in the treated groups. Overall, these findings highlight the beneficial effects of herbal extracts in managing lipid abnormalities associated with diabetes.

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