

Effect of *Andrographis paniculata* extract on serum glucose and creatinine levels in a rat model of type 2 diabetes mellitus: A systematic review

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Abstract

Background: *Andrographis paniculata* is a medicinal plant with potential antidiabetic and nephroprotective effects. However, evidence regarding its effects on glycemic control and renal outcomes in experimental diabetes remains inconsistent.

Objective: To evaluate the effects of *A. paniculata* extract on blood glucose and renal outcomes in experimental models of type 2 diabetes mellitus.

Methods: A systematic review was conducted in accordance with the PRISMA 2020 guidelines. PubMed/NCBI, ScienceDirect, Scopus, and Google Scholar were searched for studies published between 2020 and 2025. Eligible studies evaluated *A. paniculata* extract or andrographolide in rat models of type 2 diabetes mellitus and reported glycemic or renal outcomes. Because of substantial heterogeneity in animal models, interventions, outcome measures, and reporting, the findings were synthesized narratively.

Results: Eight studies were included. *A. paniculata* or andrographolide consistently improved glucose-related outcomes through enhanced insulin sensitivity, AMPK pathway activation, anti-inflammatory effects, pancreatic beta-cell protection, and GLUT4 upregulation. Doses of 100 to 400 mg/kg body weight per day administered for at least 14 days were associated with improved glycemic outcomes in standard diabetic rat models. Renal findings suggested stable or improved renal biomarkers and histopathologic outcomes, although serum creatinine was not consistently reported.

Conclusion: *A. paniculata* demonstrates promising hypoglycemic and potential nephroprotective effects in preclinical models. However, the evidence remains preliminary because of methodological heterogeneity, variable risk-of-bias reporting, and limited direct renal outcome data. Further standardized and longer-term studies are required before clinical translation.

Keywords: *Andrographis paniculata*; blood glucose; serum creatinine; systematic review; type 2 diabetes mellitus

Introduction

Diabetes mellitus is a metabolic disease characterized by hyperglycemia resulting from impaired insulin secretion, impaired insulin action, or both.¹ Prolonged hyperglycemia is associated with long-term organ damage, dysfunction, and failure and is a major contributor to numerous diabetic complications.² Diabetes is also the most common cause of progressive renal failure requiring dialysis or transplantation. Diabetic nephropathy has been reported in 30% to 40% of patients with diabetes and has become the leading cause of end-stage renal disease worldwide.^{3,4} It is characterized by structural and functional abnormalities of the kidneys. Poor glycemic control and the accumulation of advanced glycation end products (AGEs) play critical roles in the development of diabetic nephropathy.⁵

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Plants have been used as sources of traditional medicines for centuries, and numerous studies have identified them as valuable sources of potential treatments for various life-threatening diseases. Plants with antidiabetic properties are considered promising sources of new oral hypoglycemic agents. *Andrographis paniculata* (Burm. f.) has been identified as a plant with considerable antidiabetic potential.⁶ Indigenous to India, *A. paniculata* is widely cultivated throughout Southeast Asia, including Indonesia, where it is commonly used in *jamu pahitan*, a traditional Indonesian medicinal beverage, to maintain health and treat various conditions, including tonsillitis, fever, typhoid, diabetes, eczema, the common cold, diphtheria, epilepsy, gonorrhea, and syphilis.⁷

Several studies have demonstrated that *A. paniculata* extracts reduce blood glucose levels in diabetic rats.⁸ The plant contains andrographolide as its primary bioactive compound. Andrographolide exhibits diverse pharmacological activities, including anti-inflammatory, antioxidant, antibacterial, and immunomodulatory effects.^{9,10} In vitro studies have also demonstrated that *A. paniculata* extract exerts potent insulin-secretory effects in BRIN-BD11 cells, a pancreatic cell line that expresses insulin and glucokinase. In diabetic rats, andrographolide exerts hypoglycemic effects by upregulating GLUT4 messenger RNA and protein expression.⁵ Preclinical studies further suggest that andrographolide may improve insulin sensitivity and protect pancreatic beta cells from oxidative damage.¹¹

Although numerous studies have evaluated the antidiabetic effects of *A. paniculata*, considerable variation remains in the reported efficacy and safety findings, particularly with respect to renal function. The kidneys are among the primary organs affected by diabetic complications. Serum creatinine is an important marker of renal function, and uncontrolled diabetes may cause diabetic nephropathy, which is characterized by elevated serum creatinine levels. Therefore, evaluations of *A. paniculata* extract should address both its hypoglycemic efficacy and its potential renal effects. Based on this background, the research question guiding this systematic review was as follows: How effective is *A. paniculata* extract in reducing blood glucose and serum creatinine levels in rat models of type 2 diabetes mellitus? This systematic review aimed to evaluate the effectiveness of *A. paniculata* extract in reducing blood glucose levels in rat models of type 2 diabetes mellitus based on studies published during the previous five years.

Method

Eligibility criteria

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to promote transparency and reproducibility.¹² The inclusion criteria were as follows: in vivo studies involving rat (*Rattus norvegicus*) models of type 2 diabetes mellitus, studies evaluating an intervention consisting solely of *A. paniculata* extract with a clearly defined dose and treatment duration, studies measuring blood glucose as the primary outcome, studies measuring serum creatinine as a secondary outcome, studies published between 2020 and 2025, and full-text articles published in English or Indonesian. The exclusion criteria were as follows: in vitro studies, studies involving animals other than rats, clinical studies involving humans, studies evaluating combination interventions without a group receiving *A. paniculata* extract alone, studies that did not report clear blood glucose or serum creatinine data, and review articles, editorials, and conference proceedings without primary data.

Three included studies did not fully meet the eligibility criteria when interpreted strictly. These deviations are reported to ensure transparency. Ningsih et al.¹³ used an insulin-resistant HepG2 cell model rather than an in vivo rat model of type 2 diabetes mellitus. This study was retained because it provided mechanistic evidence concerning modulation of the IRS-1/GLUT2 pathway that was directly relevant to the glucose-lowering mechanism under review. Its findings were therefore treated as supportive rather than primary evidence throughout the review. Parthasarathy and Prince¹⁴ used a methotrexate-induced nephrotoxicity model, whereas Kega and Damanik¹⁵ used a high-cholesterol-diet-induced pancreatic histopathology model. Neither study used a standard streptozotocin- or alloxan-induced model of type 2 diabetes mellitus. Both studies were retained

because they reported effects of andrographolide or *A. paniculata* on glucose metabolism-related or renal outcomes considered informative for the review question. Their findings were interpreted cautiously because of the differences in disease-induction models and were identified accordingly in Tables 1 and 3. In addition, not all included studies explicitly reported serum creatinine values. Ningsih et al.¹³, Kega and Damanik¹⁵, and Liu et al.¹⁶ reported renal or glucose-related histological, biochemical, or in vitro mechanistic findings without directly reporting serum creatinine measurements. These studies were therefore treated as supportive evidence for the renal safety assessment rather than as direct evidence concerning the serum creatinine outcome. This distinction is summarized in Table 3 and discussed further in the Limitations section.

Information sources

A literature search was conducted from March 1 through March 15, 2026, in the following electronic databases: PubMed/NCBI, ScienceDirect, Scopus, and Google Scholar. Because the search was conducted in March 2026 and the eligible publication window was 2020 through 2025, all records identified through the search were published within the prespecified period. No records published in 2026 were retrieved or considered. No gray literature sources were included.

Search strategy

The PubMed/NCBI search strategy was as follows: ("Andrographis paniculata"[Mesh] OR "sambiloto" OR "andrographolide") AND ("diabetes mellitus, type 2"[Mesh] OR "type 2 diabetes" OR "insulin resistance") AND ("blood glucose"[Mesh] OR "glucose") AND ("creatinine"[Mesh]) AND ("rats"[Mesh] OR "animal model"). The ScienceDirect search strategy was as follows: ("Andrographis paniculata" OR sambiloto) AND ("type 2 diabetes" OR "diabetes mellitus") AND (glucose) AND (creatinine) AND (rat). The Scopus search strategy was as follows: (TITLE-ABS-KEY("Andrographis paniculata") OR TITLE-ABS-KEY(sambiloto)) AND (TITLE-ABS-KEY("type 2 diabetes") OR TITLE-ABS-KEY("diabetes mellitus")) AND (TITLE-ABS-KEY(glucose)) AND (TITLE-ABS-KEY(creatinine)) AND (TITLE-ABS-KEY(rat)). The Google Scholar search strategy was as follows: allintitle: "Andrographis paniculata" diabetes glucose creatinine rat.

Study selection

Study selection was conducted in three stages. First, titles and abstracts were screened to identify potentially relevant studies. Second, the full texts of potentially eligible articles were retrieved and assessed. Third, studies were included or excluded according to the predefined eligibility criteria. Title and abstract screening and full-text assessment were performed independently by two reviewers, P.H. and C.N.G. Disagreements were resolved through discussion and consensus. When consensus could not be reached, a third reviewer, T.N., adjudicated the decision. The study-selection process is presented in a PRISMA flow diagram.

Data collection

The following data were extracted from each eligible study: study characteristics including the author and year of publication; animal characteristics including rat strain and method of type 2 diabetes induction; intervention characteristics including dose, treatment duration, route of administration, and extract type; outcome parameters including blood glucose and serum creatinine levels; and key findings. Data extraction was performed independently by two reviewers, P.H. and C.N.G., using a standardized extraction form. Discrepancies were resolved through discussion and consensus or, when necessary, by consultation with a third reviewer, T.N.

Risk-of-bias assessment

Risk of bias in the selected in vivo studies was assessed using the SYRCLE risk-of-bias tool, an adaptation of the Cochrane risk-of-bias tool for animal studies. The assessed domains included sequence generation, baseline characteristics, allocation concealment, random housing, blinding, random outcome assessment, incomplete outcome data, selective outcome reporting, and other potential sources of bias.

Data synthesis

Because of substantial heterogeneity in study designs, animal models, intervention doses, and outcome reporting, the findings were synthesized qualitatively. Results were summarized descriptively according to the primary outcome, blood glucose levels, and the secondary outcome, serum creatinine levels. A quantitative meta-analysis was not performed for three reasons. First, diabetes was induced using different methods, including streptozotocin, alloxan, and a high-cholesterol diet. These models are not physiologically equivalent, and pooling their results could confound the estimated treatment effect. Second, outcome measures were reported inconsistently across studies, including absolute glucose concentrations, percentage changes, homeostatic model assessment of insulin resistance (HOMA-IR) values, and histopathologic scores. These differences prevented the use of a common effect measure. Third, several studies did not report the variance data, such as standard deviations or standard errors, required to calculate a standardized mean difference. Therefore, a narrative synthesis was considered the most appropriate and transparent approach.

Results

Study selection

A total of 347 records were initially identified: 89 from PubMed, 112 from ScienceDirect, 78 from Scopus, and 68 from Google Scholar. After 66 duplicate records were removed, 281 records remained for screening. Title and abstract screening resulted in the exclusion of 249 records, including 156 because of irrelevant titles and 93 because of ineligible abstracts.

The full texts of 32 articles were subsequently assessed for eligibility. Of these, 24 were excluded for the following reasons: five were not in vivo studies, seven did not report creatinine-related data, five did not use a type 2 diabetes model, four evaluated combination interventions, and three had no full text available. Ultimately, eight studies met the inclusion criteria and were included in this systematic review.

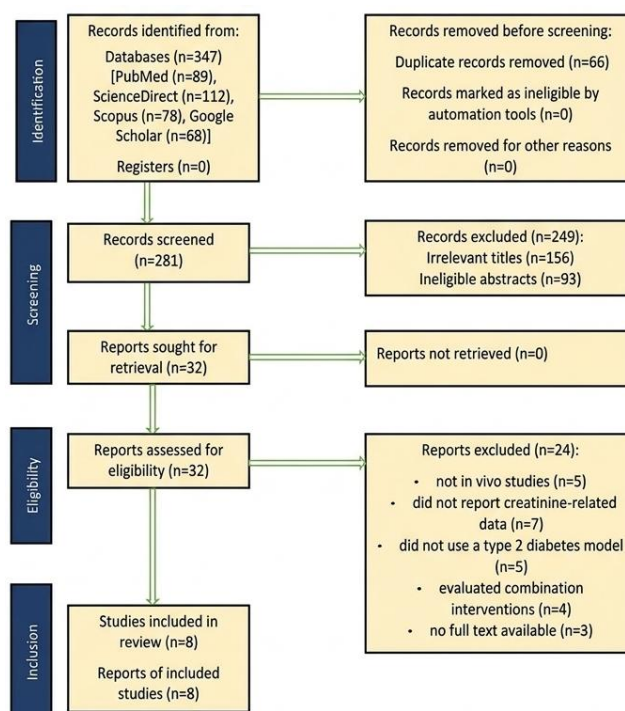


Figure 1. PRISMA flow diagram

Study characteristics

The characteristics of the eight included studies are summarized in Table 1.

Risk of bias within studies

Risk of bias was assessed using the SYRCLE risk-of-bias tool. Overall, the included studies demonstrated low-to-moderate risk of bias. The primary concerns involved insufficient reporting of allocation concealment, blinding of outcome assessors, random housing, and blinding of caregivers or investigators. Selective outcome reporting was judged to present a low risk of bias across all studies because the primary and secondary outcomes were consistently reported.

Results of individual studies

All eight included studies reported measurable effects of *A. paniculata* extract or its active compound, andrographolide, on glucose-related outcomes. However, the magnitude of the reported effect varied considerably across studies. Findings ranged from modest improvements in fasting blood glucose to reductions

of more than 40% relative to untreated diabetic controls. This variability likely reflected differences in the diabetes-induction method, dose, extract formulation, and treatment duration.

Table 1. Characteristics of the included studies

Author	Title	Year	Study design	Key findings
Hidayat and Wulandari ⁵	Effects of <i>Andrographis paniculata</i> (Burm. f.) extract on diabetic nephropathy in rats	2021	Experimental	<i>A. paniculata</i> extract at 200 and 400 mg/kg improved the renal hypertrophy index. SOD, catalase, and GSH activities were significantly reduced in streptozotocin-induced diabetic rats compared with controls. The extract significantly reduced malondialdehyde levels at both doses.
Jaiyesimi et al. ¹⁷	Polyphenol-rich extracts of <i>Andrographis paniculata</i> mitigate hyperglycemia by attenuating beta-cell dysfunction, proinflammatory cytokines, and oxidative stress in alloxan-induced diabetic Wistar albino rats	2020	Experimental	Significant differences ($p < 0.05$) were observed in hematologic indices, hepatic biomarkers, total protein levels, antioxidant enzyme activity, total thiol levels, and fasting blood glucose levels in diabetic rats treated with polyphenol-rich <i>A. paniculata</i> extract compared with untreated diabetic controls. Serum insulin and hexokinase and glucose-6-phosphatase activities also differed significantly. The inflammatory biomarkers IL-6 and TNF-alpha were significantly reduced in the treated group.
Saka et al. ¹⁸	<i>Andrographis paniculata</i> improves glucose regulation by enhancing insulin sensitivity and upregulating GLUT4 expression in Wistar rats	2024	Experimental	Treatment with <i>A. paniculata</i> improved insulin sensitivity, as indicated by increased HOMA-beta and HOMA-S values and decreased TyG index and HOMA-IR values compared with controls. Fasting blood glucose, glycosylated hemoglobin, and atherogenic dyslipidemia, including the atherogenic index of plasma, also improved.
Ningsih et al. ¹³	<i>Andrographis paniculata</i> (Burm. f.) Nees extract ameliorates insulin resistance in insulin-resistant HepG2 cells through the GLUT2/IRS-1 pathway	2024	Experimental	Sambiloto extract ameliorated insulin resistance in high-glucose-induced insulin-resistant HepG2 cells by modulating the IRS-1/GLUT2 pathway through IL-6 inhibition, demonstrating anti-inflammatory and insulin-sensitizing potential.
Yin et al. ¹⁹	Andrographolide as a multitarget therapeutic agent in diabetic nephropathy: Insights into STAT3/PI3K/Akt pathway modulation	2025	Experimental	Andrographolide significantly improved renal function in streptozotocin-induced diabetic nephropathy rats by reducing proteinuria, glomerular hypertrophy, and renal fibrosis. It also alleviated oxidative stress, reduced proinflammatory cytokine levels, and enhanced antioxidant enzyme activity. In vitro, andrographolide suppressed high-glucose-induced podocyte oxidative stress and apoptosis through inhibition of the RAGE/NF-kB and STAT3/PI3K/Akt pathways.
Parthasarathy and Prince ¹⁴	Methotrexate-induced intestinal and nephrotoxicity attenuated by <i>Andrographis paniculata</i> through amelioration of oxidative stress, inflammation, and apoptosis	2024	Experimental	Aqueous <i>A. paniculata</i> extract attenuated increases in renal biomarkers and intestinal and renal MDA, TNF-alpha, IL-6, caspase-3, and caspase-8 levels, as well as histopathologic alterations. The extract restored intestinal and renal antioxidant enzyme activities, IL-10, and BCL-2 levels, thereby preserving intestinal and renal function and reducing cellular damage.
Kega and Damanik ¹⁵	Effects of <i>Andrographis paniculata</i> leaf extract on pancreatic histopathologic findings in white rats (<i>Rattus norvegicus</i>) fed a high-cholesterol diet	2025	Experimental	Bivariate analysis demonstrated a significant effect of sambiloto extract on pancreatic histopathology in Wistar rats fed a high-cholesterol diet ($p = 0.001$). The most effective dose for pancreatic cell repair was 800 mg/kg body weight.
Liu et al. ¹⁶	Effects of andrographolide on renal tubulointerstitial injury and fibrosis: Evidence of its mechanism of action	2021	Experimental	In vitro, andrographolide at concentrations of 5 and 10 μ M inhibited high-glucose-induced apoptosis, epithelial-mesenchymal transition, and collagen deposition in HK-2 cells. In vivo, andrographolide at doses of 2 and 4 mg/kg inhibited renal tubular apoptosis, epithelial-mesenchymal transition, tubulointerstitial fibrosis, mitochondrial dysfunction, and NLRP3 inflammasome activation in diabetic rats.

Table 2. Summary of risk of bias across the included studies using the SYRCLE Risk-of-Bias Tool

SYRCLE domain	Overall judgment*	Basis for judgment
Sequence generation (selection bias)	Unclear	The methods used to randomly allocate animals to groups were not explicitly described in most studies.
Baseline characteristics	Low	Baseline body weight and glucose comparability across groups were reported before the intervention in all studies.
Allocation concealment (selection bias)	Unclear	Concealment of group allocation during disease induction and dosing was not reported in most studies.
Random housing (performance bias)	Unclear	Randomization of animal housing locations or conditions was not reported in most studies.
Blinding of caregivers or investigators (performance bias)	Unclear	Blinding of personnel administering the interventions was not reported in most studies.
Random outcome assessment and blinding of assessors (detection bias)	Unclear	Blinding of outcome assessors, including those conducting biochemical and histologic analyses, was not reported in most studies.
Incomplete outcome data (attrition bias)	Low	No unexplained animal losses or exclusions were identified in any included study.
Selective outcome reporting (reporting bias)	Low	The prespecified primary and secondary outcomes were reported in all included studies.
Other sources of bias	Unclear	Insufficient methodological detail in several studies prevented a complete assessment of potential biases, including extract standardization and sample-size justification.

*Judgments are presented at the domain level and aggregated across the eight included studies to reflect the overall reporting pattern. A study-level breakdown was not provided because sufficient methodological detail to make independent judgments for several domains, including allocation concealment and blinding, was not consistently available in the original publications. The completed SYRCLE assessment forms are available from the corresponding author upon reasonable request.

Table 3. Overview of renal-related outcome reporting across the included studies

Study	Serum creatinine explicitly reported?	Renal-related finding
Hidayat and Wulandari ⁵	Not explicitly reported	The renal hypertrophy index improved, and oxidative stress markers, including SOD, catalase, GSH, and MDA, improved at doses of 200 to 400 mg/kg. A direct serum creatinine value was not stated in the summarized findings.
Jaiyesimi et al. ¹⁷	No	The study focused on hematologic, hepatic, and glycemic biomarkers; no renal outcome was reported.
Saka et al. ¹⁸	No	The study focused on insulin sensitivity, glycemic control, and lipid indices; no renal outcome was reported.
Ningsih et al. ¹³	No, in vitro model	This HepG2 cell-based study did not assess renal function.
Yin et al. ¹⁹	Not explicitly reported	Reduced proteinuria, glomerular hypertrophy, and renal fibrosis were reported as indicators of improved renal status. A direct serum creatinine value was not stated in the summarized findings.
Parthasarathy and Prince ¹⁴	Not explicitly reported	The study reported attenuation of elevated renal biomarkers and renal oxidative and inflammatory markers; serum creatinine was not individually identified in the summarized findings.
Kega and Damanik ¹⁵	No	The study focused on pancreatic histopathology in a high-cholesterol-diet model and did not report a renal outcome.
Liu et al. ¹⁶	No	Renal tubulointerstitial injury and fibrosis markers, including apoptosis, epithelial-mesenchymal transition, and fibrosis, were reported. A direct serum creatinine value was not stated in the summarized findings.

Note: This table reflects the renal-related findings summarized from the original publications in Table 1 of this review. Three studies, namely Jaiyesimi et al.¹⁴, Saka et al.¹⁸, and Kega and Damanik¹⁵, did not report renal outcomes and were included on the basis of their glycemic or mechanistic findings only, as described in the eligibility criteria section. The remaining five studies reported renal-related outcomes, but not all explicitly provided numeric serum creatinine values. This distinction was not always clear from the available summarized data and requires verification against the full text of each primary study.

The reported doses ranged from 100 to 800 mg/kg body weight per day, and treatment durations ranged from 14 to 28 days. Regarding renal outcomes, studies that reported renal biomarkers generally showed stable or improved values after treatment. Several studies also documented improvements in renal histopathology. Three studies did not directly report serum creatinine and instead contributed supportive mechanistic or histologic evidence, as shown in Table 3.

Results of the synthesis

The qualitative synthesis indicated that *A. paniculata* extract improved glucose-related outcomes in experimental models through several proposed mechanisms. These mechanisms included activation of the AMPK pathway and enhanced insulin sensitivity, suppression of proinflammatory cytokines such as TNF-alpha and IL-6, protection of pancreatic beta cells from oxidative injury, and upregulation of GLUT4 expression. Regarding renal safety, among the studies that explicitly reported serum creatinine, all showed stable or improved values, and several additionally documented nephroprotective effects through attenuation of oxidative stress, inflammation, fibrosis, and NLRP3 inflammasome activation in renal tissue (Table 3).

Discussion

This systematic review found that *Andrographis paniculata* extract consistently improved glycemic outcomes in rat models of type 2 diabetes mellitus, with additional evidence suggesting potential nephroprotective effects. These findings are consistent with previous reports indicating that andrographolide may help prevent diabetes-related complications, including cognitive impairment, diabetic nephropathy, and retinopathy.²⁰

The findings reported by Saka et al.¹⁸ are also noteworthy. In addition to reducing blood glucose levels under diabetic conditions, *A. paniculata* reduced post-load glucose levels 1 hour after glucose administration in nondiabetic animals. This effect was attributed to simultaneous improvements in insulin sensitivity and beta-cell function.²¹ Although based on a single study, this observation raises the possibility that *A. paniculata* may have a dual role in the management of established T2DM and the prevention of insulin resistance in nondiabetic conditions. However, this hypothesis requires confirmation in appropriately designed studies.

Saka et al.¹⁸ also reported improvements in indices of atherogenic dyslipidemia, including HDL-C, the atherogenic index of plasma, and the Castelli risk index I, without a concomitant change in body weight. Because this was a secondary and exploratory finding from a single study and was not evaluated in the other seven studies, it is mentioned only as a potential cardiometabolic benefit requiring dedicated investigation. It was not incorporated into the primary interpretation or conclusions of this review.^{22,23}

This review has several limitations. Methodological heterogeneity in diabetes induction, extract preparation, dose, and treatment duration precluded meta-analysis, as the streptozotocin, alloxan, and high-cholesterol diet models are not directly comparable. Incomplete reporting of allocation concealment, blinding, and random housing may also have led to overestimation of treatment effects. Three studies used nonstandard models, including insulin-resistant HepG2 cells, methotrexate-induced nephrotoxicity, and high-cholesterol-diet-induced pancreatic injury; therefore, their findings should be considered supportive rather than confirmatory.^{13–15} Publication bias and certainty of evidence were not formally assessed because of the small number of studies and narrative synthesis. Given the preclinical evidence base, methodological heterogeneity, and unclear risk of bias, the certainty of evidence for glycemic and renal outcomes is considered low to moderate. Future research should use standardized extracts, rigorous randomized designs, formal bias and evidence-certainty assessments, and comprehensive pharmacokinetic and pharmacodynamic evaluations.

The consistent preclinical evidence supporting the hypoglycemic and potentially nephroprotective effects of *A. paniculata* provides a rationale for further clinical investigation. However, several translational challenges must be addressed before clinical studies can be appropriately designed. Interspecies differences in drug absorption, distribution, metabolism, and excretion mean that effective doses in rodents, such as 100 to 400 mg/kg body weight, cannot be directly converted into human doses. Formal allometric scaling and pharmacokinetic bridging

studies are required to establish a scientifically justified human-equivalent dose. Extract standardization is also essential because andrographolide content may vary substantially among preparations. A validated dosing regimen for human use must therefore be established before clinical translation. In addition, the current evidence is limited to rodent and in vitro models with relatively short intervention periods of 14 to 28 days. The long-term safety of *A. paniculata*, including its potential hepatic, renal, and drug-interaction effects when administered with antidiabetic medications, has not been established. Dedicated toxicology and phase I studies are therefore needed before dose-finding clinical trials in patients with T2DM can be justified.

Conclusion

This systematic review found that *Andrographis paniculata* extract improves glycemic outcomes in experimental models of type 2 diabetes mellitus, with proposed effects involving enhanced insulin sensitivity, AMPK pathway activation, anti-inflammatory activity, protection of pancreatic beta cells, and increased GLUT4 expression. Doses of 100 to 400 mg/kg body weight per day administered for at least 14 days were associated with improved glucose-related outcomes in standard streptozotocin- or alloxan-induced models. The available evidence also suggests potential nephroprotective effects, including improvements in renal biomarkers, oxidative stress, fibrosis, and renal histopathology. However, serum creatinine was not consistently reported, and several included studies used nonstandard models or provided supportive rather than direct evidence of renal effects. Because the evidence was derived from a small number of heterogeneous preclinical studies with variable risk-of-bias reporting, its certainty remains low to moderate. Further studies using standardized extracts, rigorous experimental designs, longer follow-up periods, and comprehensive safety and pharmacokinetic assessments are needed before clinical application of *A. paniculata* in patients with T2DM can be considered.

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