Review

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Review

Unlocking the Anti-Obesity Potential of the Genus *Scutellaria*: Pharmacological Insights and Therapeutic Perspectives

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Abstract

Obesity represents a growing global health challenge, driving the need for safer and more effective therapeutic strategies. Natural products, particularly medicinal plants, have gained increasing attention as potential sources of anti-obesity agents due to their diverse bioactive compounds and multi-target mechanisms. The genus *Scutellaria* (Lamiaceae) is rich in phytochemicals, especially flavonoids such as baicalin, baicalein, and wogonin, which have been reported to modulate key metabolic pathways involved in obesity. This review aims to comprehensively summarize current evidence on selected *Scutellaria* species with potential anti-obesity activity, focusing on their phytochemical profiles and pharmacological mechanisms. A literature search was conducted using PubMed, Scopus, and Google Scholar databases, and relevant studies were selected based on predefined inclusion criteria. The findings indicate that *Scutellaria*-derived compounds may exert anti-obesity effects through multiple mechanisms, including inhibition of adipogenesis, regulation of lipid metabolism, improvement of energy homeostasis, and suppression of obesity-associated inflammation. Preclinical studies provide substantial evidence supporting these biological activities; however, clinical validation remains limited. In conclusion, *Scutellaria* species represent promising candidates for the development of novel anti-obesity therapies. Further studies, particularly well-designed clinical trials, are necessary to confirm their efficacy, safety, and therapeutic applicability in humans.

Keywords: *Scutellaria*; anti-obesity; flavonoids; adipogenesis; lipid metabolism; phytochemicals; metabolic regulation

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1. Introduction

Obesity has become a major global public health concern, with its prevalence increasing markedly across diverse regions. Recent reports highlight a continuous rise in obesity rates, particularly in the Americas and Europe, where the burden remains among the highest worldwide [1]. Projections from the World Obesity Atlas further indicate a substantial increase in the number of individuals affected in the coming decades, underscoring the escalating scale of this health challenge [2]. In addition, obesity is strongly associated with a wide range of comorbidities, including type 2 diabetes, cardiovascular diseases, and metabolic syndrome, thereby emphasizing the urgent need for effective prevention and management strategies [3].

Pharmacological interventions are widely employed in the management of obesity; Nevertheless, currently available therapies present several limitations. Many synthetic anti-obesity agents exhibit variable efficacy and are often associated with adverse effects, particularly involving the gastrointestinal and pancreatic systems [4,5]. Furthermore, high treatment costs and limited accessibility remain significant barriers, especially in low- and middle-income populations [6,7]. These challenges have driven ongoing efforts to identify safer, more effective, and more accessible therapeutic alternatives targeting obesity-related metabolic disturbances.

In this context, phytochemical compounds derived from medicinal plants have attracted considerable attention due to their potential roles in metabolic regulation. Bioactive classes such as flavonoids, polyphenols, and alkaloids have been reported to influence key processes involved in obesity, including adipogenesis, lipid metabolism, and energy homeostasis [8–11]. Preclinical evidence suggests that these plant-derived compounds may improve metabolic parameters by modulating molecular pathways associated with fat accumulation and energy balance [12,13]. Such findings support the continued exploration of plant-based compounds as promising sources of novel anti-obesity agents.

Among these, the genus *Scutellaria* (family *Lamiaceae*) has gained increasing scientific interest due to its rich and diverse phytochemical composition. Notably, flavonoids such as baicalin, baicalein, and wogonin have been widely studied for their biological activities [12–15]. These compounds have been reported to regulate adipocyte differentiation, modulate lipid metabolism, and attenuate inflammatory processes involved in obesity pathogenesis. Moreover, accumulating evidence indicates that extracts and isolated constituents from *Scutellaria* species can influence key metabolic pathways related to lipid accumulation and energy regulation [14,16,17].

Therefore, this review aims to comprehensively summarize current studies on selected *Scutellaria* species and evaluate their potential as anti-obesity agents, with particular emphasis on their bioactive compounds and underlying mechanisms of action in obesity-related metabolic pathways.

2. Methods

A comprehensive literature search was conducted to identify studies investigating the phytochemistry and anti-obesity potential of *Scutellaria* species. Electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, were systematically searched for relevant articles published up to 2026. The search strategy employed combinations of keywords such as "*Scutellaria*", "skullcap", "anti-obesity", "antiobesity", "adipogenesis", "lipid metabolism", "flavonoids", "baicalin", "baicalein", and "wogonin". Additional records were identified through manual screening of reference lists from relevant articles.

The study selection process was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A total of 2,798 records were initially identified, including 2,687 records from electronic databases and 111 additional records from other sources. After removal of duplicates, 1,351 records remained for title and abstract screening.

During the screening phase, 871 records were excluded based on irrelevance to the topic. The remaining 498 full-text articles were assessed for eligibility. Of these, 334 articles were excluded for the following reasons: lack of relevance to obesity (n = 167), insufficient mechanistic or experimental detail (n = 113), non-English language (n = 17), and duplication or overlap with previously included reviews (n = 37).

Ultimately, 164 studies were included in the qualitative synthesis. Data from the selected studies were extracted and categorized according to *Scutellaria* species, phytochemical constituents, experimental models, and reported anti-obesity mechanisms. The findings were then synthesized narratively, with emphasis on mechanistic insights and critical evaluation of the available evidence.

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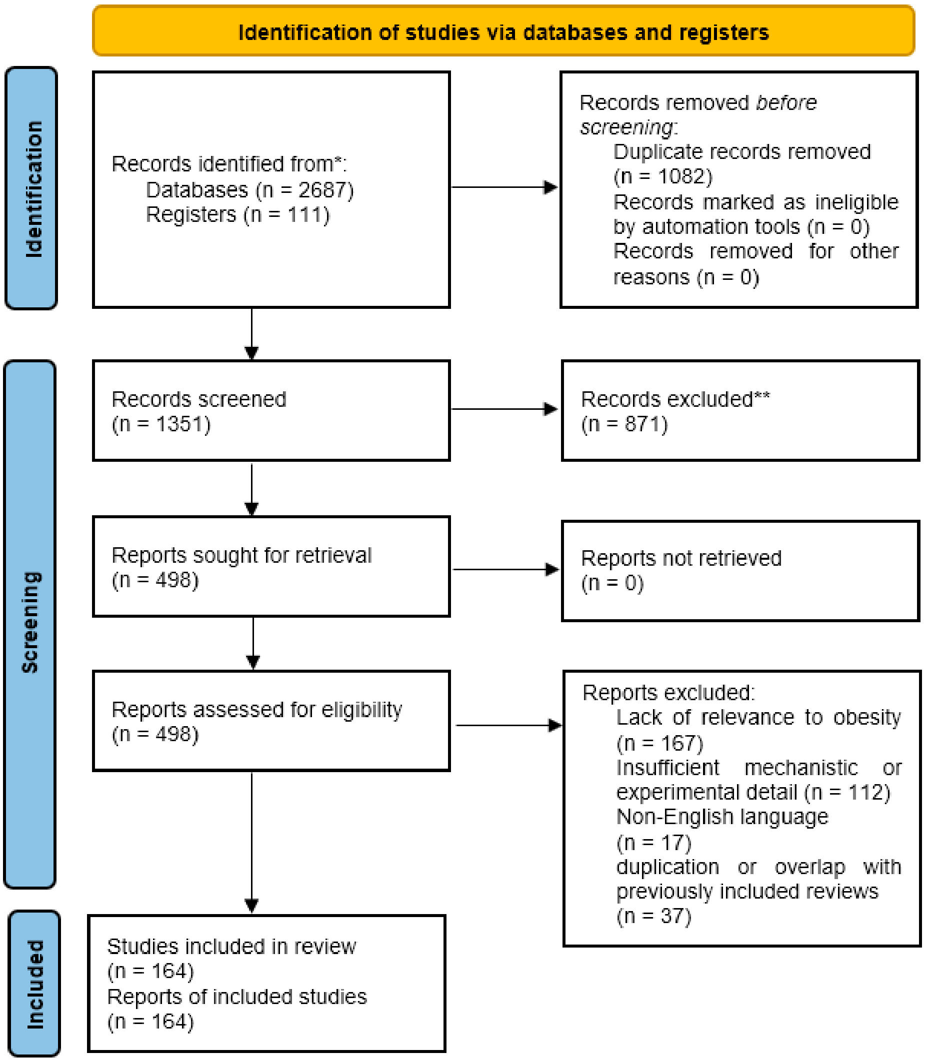

Figure 1. PRISMA flow diagram showing the process of literature identification, screening, eligibility assessment, and inclusion. A total of 2,798 records were initially identified, with 1,351 remaining after duplicate removal. Following title and abstract screening, 498 articles were assessed for full-text eligibility, and 164 studies were ultimately included in the qualitative synthesis.

3. The Genus Scutellaria

The figure illustrates the remarkable morphological diversity within the genus *Scutellaria*, particularly in terms of floral architecture, pigmentation, and inflorescence arrangement. Despite sharing the characteristic bilabiate corolla and the distinctive dorsal appendage (scutellum), individual species exhibit substantial variation in flower size, color spectrum (ranging from white and yellow to deep purple and red), and structural complexity. This diversity reflects the broad ecological adaptability of the genus and its evolutionary radiation across different geographical regions [18–22].

From a taxonomic perspective, floral morphology remains a key diagnostic feature for species identification within *Scutellaria*. Variations in corolla shape, calyx structure, and reproductive organs contribute to species differentiation, although these traits may sometimes overlap, complicating classification. Recent phylogenomic studies suggest that morphological diversity within the genus is not always congruent with genetic relationships, indicating potential convergent evolution driven by environmental and pollination pressures [23,24].

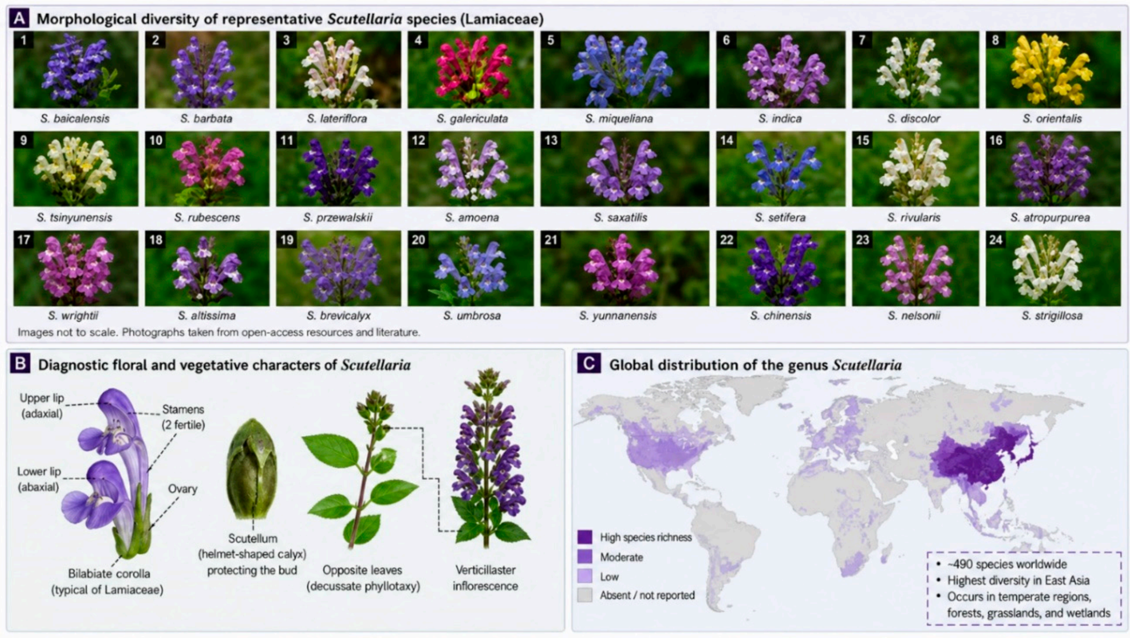

Figure 2. Morphological and geographic diversity of genus *Scutellaria*. **(A)** Floral diversity of 24 representative species showing variation in color and inflorescence architecture. **(B)** Diagnostic floral and vegetative characters typical of *Scutellaria*. **(C)** Global distribution pattern of the genus, with the highest species richness in East Asia. **Species list**: (1) *S. baicalensis*, (2) *S. barbata*, (3) *S. lateriflora*, (4) *S. galericulata*, (5) *S. miqueliana*, (6) *S. indica*, (7) *S. discolor*, (8) *S. orientalis*, (9) *S. tsinyuensis*, (10) *S. rubescens*, (11) *S. przewalskii*, (12) *S. amoena*, (13) *S. saxatilis*, (14) *S. setifera*, (15) *S. rivularis*, (16) *S. atropurpurea*, (17) *S.wrightii*, (18) *S. altissima*, (19) S. *brevicalyx*, (20) *S. umbrosa*, (21) *S. yunnanensis*, (22) *S. chinensis*, (23) *S. nelsonii*, (24) *S. Strigillosa.*

In the Indonesia endemic *Scutellaria slametensis*, differences in flower were observed between individuals from Cibodas Botanical Garden and Baturraden Botanical Garden. This variation may be related to environmental factors such as altitude, temperature, and light, as well as pollination pressure.

Notably, morphological variation may also have implications for phytochemical diversity. Differences in plant organs, particularly between aerial parts and roots, have been associated with distinct profiles of secondary metabolites, including flavonoids, terpenoids, and phenolic compounds. As these metabolites underpin the pharmacological activities of *Scutellaria* species, including their proposed anti-obesity effects, morphological diversity may indirectly reflect biochemical and functional heterogeneity within the genus [25].

However, current research rarely integrates morphological, phytochemical, and pharmacological data in a systematic manner. Most studies focus on a limited number of species, particularly *S. baicalensis*, without considering broader interspecies variation. This represents a critical gap, as comparative analyses across morphologically distinct species could provide valuable insights into structure–activity relationships and aid in the identification of novel bioactive compounds.

Overall, the diversity depicted in this figure underscores the complexity of the genus *Scutellaria* and highlights the need for integrative approaches that combine taxonomy, phytochemistry, and pharmacology to fully elucidate its therapeutic potential.

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Figure 3. Variation in flower coloration of *Scutellaria slametensis*. **(D1)** Plant growing in its natural habitat on *Mt. Slamet* (in situ). **(D2)** Specimens collected from Cibodas Botanical Garden showing predominantly purplish flowers. **(D3)** Specimen from Baturraden Botanical Garden (ex situ *collection*) showing pinkish flowers.

4. Phytochemical Constituents of Selected *Scutellaria* Species

Species within the genus *Scutellaria* exhibit considerable chemical heterogeneity, reflecting variations in geographic distribution, plant part, and extraction methodologies [26–28]. Among the identified metabolites, flavonoids constitute the dominant class, accompanied by phenolic acids, terpenoids, iridoids, and other secondary metabolites. These compounds collectively contribute to the diverse biological activities attributed to the genus.

Despite this, despite extensive phytochemical characterization, the available data remain unevenly distributed across species, with a disproportionate focus on a limited number of well-studied taxa, particularly *S. baicalensis*. In addition, inconsistencies in analytical approaches and reporting standards complicate direct comparison between studies.

The phytochemical diversity of the genus *Scutellaria* is extensive and encompasses numerous species with distinct metabolite profiles. To improve clarity and emphasize the most pharmacologically relevant taxa, Table 1 summarizes representative *Scutellaria* species frequently investigated for their bioactive constituents and metabolic regulatory potential. A comprehensive phytochemical inventory of additional *Scutellaria* species is provided in Supplementary Table S1.

Table 1. Representative phytochemical profiles of selected *Scutellaria* species (condensed and standardized).

Species	Plant Part	Dominant Phytochemical Classes	Representative Compounds	References
S. baicalensis	Root, aerial	Flavonoids, phenolics, terpenoids	Baicalin, baicalein, wogonin, wogonoside	[29–34]
S. barbata	Root, aerial	Diterpenoids, flavonoids, volatiles	Scutellarin, luteolin, neo-clerodanes	[30,33,35,36]
S. lateriflora	Aerial tissue	Flavonoids, indole derivatives	Baicalin, scutellarin, verbascoside	[30,37–40]
S. adenostegia	Aerial, root	Flavonoids, volatiles	Apigenin, luteolin, baicalein	[41,42]

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S. albida	Aerial	Iridoids, phenylethanoids, flavonoids	Catalpol, verbascoside, scutellarin	[44–46]
S. alpina	Callus, aerial	Flavonoids, terpenoids	Baicalin, luteolin, wogonoside	[47,48]
S. altissima	Root, aerial	Flavonoids, phenylpropanoids	Baicalin, luteolin, myristicin	[33,49–51]
S. amoena	Aerial	Flavonoids	Baicalin, wogonin, oroxylin A	[53]
S. araxensis	Root, aerial	Flavonoids, iridoids, phenolics	Chrysin, wogonin, tricin	[55–57]
S. bornmuelleri	Root, aerial	Flavonoids, phenylethanoids	Wogonin, baicalin, verbascoside	[55,61,62]
S. galericulata	Aerial	Flavonoids, diterpenoids	Wogonin, scutellarein, baicalein	[75–77]
S. indica	Aerial, root	Flavonoids	Baicalin, wogonin, naringenin	[34,92,93]
S. multicaulis	Root, aerial	Flavonoids, terpenoids	Pectolinarin, chrysin, wogonin	[69,97]
S. orientalis	Root, aerial	Flavonoids, volatiles	Baicalein, chrysin, scutellarin	[55,97,101,102]
S. rivularis	Aerial	Flavonoids, diterpenoids	Baicalin, baicalein, scutellone D	[115,116]
S. scordiifolia	Aerial	Flavonoid glycosides	Scutellarein derivatives	[122]
S. viscidula	Aerial, root	Flavonoids	Baicalin, wogonin, viscidulin	[126]
S. wrightii	Aerial, root	Flavonoids	Chrysin, baicalin, scutellarin	[33]

Although *Scutellaria* species contain a broad range of phytochemicals, current anti-obesity evidence is concentrated primarily on flavonoids from *S. baicalensis*, particularly baicalin, baicalein, and wogonin. These compounds appear to act through multi-target mechanisms, including suppression of adipogenesis, activation of AMPK-mediated lipid catabolism, inhibition of inflammatory signaling, and improvement of insulin sensitivity. Despite this most findings remain preclinical, and differences in experimental models, extract standardization, dose selection, and compound bioavailability limit direct translational interpretation.

As summarized in Table 2**,** AMPK activation appears to be one of the most consistently reported mechanism and the major proposed anti-obesity mechanisms of *Scutellaria*-derived compounds and highlights the current evidentiary limitations. Table 2 also highlights the predominance of cellular and animal models in anti-obesity research.

Table 2. Anti-obesity mechanisms of major *Scutellaria*-derived compounds and extracts.

Compound/Extract	**Source species**	**Experimental model**	**Main anti-obesity mechanism**	**Reported metabolic effects**	**Critical note**
Baicalin	*S. baicalensis*, several *Scutellaria spp*	3T3-L1 adipocytes; HFD-induced obese models	Activation of AMPK/ACC pathway; suppression of lipogenesis; promotion of thermogenesis via UCP1 upregulation and browning pathways; activation of hepatic CPT1-	Reduced lipid accumulation, adipocyte hypertrophy, hepatic lipid deposition, and body-weight gain	Strong preclinical evidence, but limited human validation

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			mediated fatty acid β-oxidation [128–131]		
Baicalein	*S. baicalensis* several *Scutellaria* spp	Adipocytes; metabolic disease models; Western diet-induced obese mice	Inhibition of adipogenesis via downregulation of PPAR γ/C/EBPα and suppression of mTOR signaling; reduction of lipogenesis (SREBP-1, Lipin1); Nrf-2 mediated immunometabolic activation of adipose tissue macrophages [132–134]	Decreased adipocyte differentiation and intracellular triglyceride accumulation	Mechanistic evidence predominantly cellular, with limited in vivo validation
Wogonin	*S. baicalensis* several *Scutellaria* spp	Adipocytes; obesity-associated inflammation models	Suppression of inflammatory signaling; modulation of adipose tissue inflammation and insulin resistance [135–137]	Improved inflammatory profile, glucose metabolism, and lipid regulation	Promising, but often studied in combination or non-obesity models
Wogonoside/Norwogonoside	*S. baicalensis* several *Scutellaria* spp	Preclinical metabolic models	Regulation of lipid metabolism and inflammatory mediators [138,139]	Potential improvement in metabolic dysfunction and adipose inflammation	Anti-obesity-specific data remain less extensive than baicalin
Scutellarin / Scutellarein	*S. baicalensis* several *Scutellaria* spp	Adipocyte and metabolic models	Inhibition of adipogenesis and oxidative-inflammatory signaling; enhancement of autophagy and suppression of IRE1α/XBP1-mediated lipogenesis [140–142]	Reduced lipid accumulation and obesity-related inflammatory responses	Requires more direct obesity-focused validation
Oroxylin A	*S. baicalensis* several *Scutellaria* spp	In vitro and preclinical models	Modulation of lipid metabolism, oxidative stress, and inflammatory pathways [143–145]	Potential improvement in lipid homeostasis and metabolic stress	Evidence is pharmacologically relevant but not yet obesity-specific enough
Chrysin	Several *Scutellaria* spp.	Adipocyte and metabolic models	Downregulation of adipogenic transcription factors; antioxidant activity [146–148]	Reduced adipogenesis and oxidative stress associated with metabolic dysfunction	Poor bioavailability may limit translational relevance
Apigenin	*S. adenostegia, S. araxensis*	Adipocytes; metabolic models	Inhibition of adipocyte differentiation; AMPK-related lipid regulation [149–151]	Reduced lipid accumulation and improved metabolic signaling	Not unique to *Scutellaria*; attribution should be cautious

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Luteolin	*S. adenostegia*, *S. altissima*	Adipocyte and inflammation models	Anti-inflammatory activity; regulation of adipogenesis and lipid metabolism [152,153]	Suppressed adipocyte differentiation and inflammatory mediator production	Needs species-specific anti-obesity confirmation
S. baicalensis extract	*S. baicalensis*	HFD-induced obesity; insulin resistance models	Regulation of adipose inflammation, lipid metabolism, and insulin signaling [154,155]	Improved insulin resistance, reduced inflammatory markers, and improved metabolic parameters	Extract composition varies across studies
S. baicalensis + *Phyllostachys pubescens* combination	*S. baicalensis*	3T3-L1 adipocytes; HFD-induced obese mice	AMPK activation; browning/thermogenesis enhancement [156]	Reduced adipogenesis; increased thermogenic markers and energy expenditure	Combination design limits attribution to *Scutellaria* alone
S. barbata constituents	*S. barbata*	Mostly non-obesity pharmacological models	Anti-inflammatory, antioxidant, and metabolic regulatory potential [157,158]	Possible relevance to obesity-associated inflammation	Direct anti-obesity evidence remains limited
S. lateriflora	*S. lateriflora*	Anti-inflammatory models, primarily neuropharmacology	Putative AMPK, anti-inflammatory metabolic modulation, antioxidant [159,160]	Possible relevance to obesity-associated inflammation	No direct anti-obesity evidence
S. indica constituents	*S. indica*	Mostly non-obesity pharmacological models, no validated obesity-specific model reported	Putative metabolic regulation via antioxidant, anti-inflammatory activity [161,162]	Possible relevance to obesity-associated inflammation	No direct anti-obesity evidence
S. galericulata constituents	*S. galericulata*	Non-obesity inflammatory models	Antiinflammatory activity via suppression of TNF-α, IL-6, IL-8 [163,164]	Possible relevance to obesity-associated inflammation	No direct anti-obesity evidence
Scutellaria spp constituents	Several *scutellaria* spp	Non-obesity inflammatory models	Antioxidant effect	Possible relevance to obesity-associated oxidative stress	No direct anti-obesity evidence

5. Results and Discussion

The included studies were analyzed and synthesized based on phytochemical composition and underlying anti-obesity mechanisms, as summarized below.

5.1. Phytochemical Drivers of Anti-Obesity Activity

The anti-obesity potential of *Scutellaria* species is largely attributed to their rich flavonoid content, particularly baicalin, baicalein, and wogonin, which have been consistently identified across multiple species. These compounds represent structurally related flavones that exhibit broad biological activities, including modulation of metabolic and inflammatory pathways relevant to obesity. In addition to flavonoids, other classes such as phenolic acids, terpenoids, and iridoids may contribute synergistically; Conversely, their roles remain comparatively underexplored.

A notable limitation across the literature is the predominant focus on a small subset of compounds, particularly those derived from *S. baicalensis*, while many other species remain chemically characterized but pharmacologically underinvestigated. This imbalance restricts the ability to generalize findings across the genus and suggests that the therapeutic potential of less-studied *Scutellaria* species may be underestimated.

5.2. Modulation of Adipogenesis and Lipid Metabolism

A central mechanism underlying the anti-obesity effects of *Scutellaria*-derived compounds is the regulation of adipogenesis. Several studies report that baicalin, baicalein, and related flavonoids inhibit adipocyte differentiation through downregulation of key transcription factors, including peroxisome proliferator-activated receptor gamma (PPARγ) and CCAAT/enhancer-binding proteins (C/EBPs). These transcription factors play critical roles in adipocyte maturation and lipid accumulation, and their suppression is associated with reduced adipogenesis in in vitro models.

In parallel, these compounds have been shown to influence lipid metabolism by activating AMP-activated protein kinase (AMPK), a central regulator of cellular energy homeostasis. Activation of AMPK promotes fatty acid oxidation while inhibiting lipogenesis, thereby contributing to reduced lipid accumulation in adipose and hepatic tissues. While these findings are mechanistically consistent, they are largely derived from controlled experimental systems, and their physiological relevance in humans remains to be fully established.

5.3. Anti-Inflammatory and Metabolic Regulatory Effects

Chronic low-grade inflammation is a hallmark of obesity and contributes significantly to metabolic dysfunction. *Scutellaria*-derived flavonoids, particularly wogonin and baicalein, have demonstrated anti-inflammatory properties through the suppression of pro-inflammatory cytokines and signaling pathways, including NF-κB. These effects may indirectly improve insulin sensitivity and metabolic homeostasis.

Despite this, the distinction between primary anti-obesity effects and secondary anti-inflammatory benefits is often unclear. Many studies do not differentiate whether observed metabolic improvements result from direct modulation of adipose tissue biology or from broader systemic anti-inflammatory effects. This ambiguity highlights the need for more targeted mechanistic studies to clarify causality.

5.4. Energy Homeostasis and Thermogenic Regulation

Emerging evidence suggests that certain *Scutellaria* extracts may influence energy expenditure by promoting thermogenesis and adipose tissue browning, potentially via AMPK-related pathways. Such effects represent a promising mechanism, as they address energy imbalance rather than solely inhibiting fat accumulation. Nonetheless, these findings are relatively limited and often involve combination extracts or multi-component formulations, making it difficult to attribute specific effects to individual *Scutellaria*-derived compounds.

5.5. Clinical Perspective

Despite substantial preclinical evidence, clinical evaluation of *Scutellaria*-derived compounds in obesity remains extremely limited. Current human studies primarily focus on the anti-inflammatory, hepatoprotective, or metabolic effects of *Scutellaria baicalensis* formulations rather than obesity-

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specific endpoints. Moreover, issues related to compound bioavailability, pharmacokinetic variability, and extract standardization continue to complicate clinical translation. Consequently, the therapeutic relevance of *Scutellaria* in obesity management remains largely unvalidated in human populations.

6. Translational Limitations and Research Gaps

Despite promising preclinical findings, several critical limitations hinder the translation of *Scutellaria* research into clinical application. First, the majority of studies are restricted to in vitro systems or animal models, with a notable lack of well-designed human trials. Second, variability in extraction methods, compound purity, and dosing regimens reduces reproducibility and comparability across studies. Third, issues related to bioavailability and pharmacokinetics of key flavonoids, such as baicalin and chrysin, remain insufficiently addressed, raising concerns about their in vivo efficacy.

Additionally, the frequent use of multi-component extracts complicates the identification of active constituents and their precise mechanisms of action. While synergistic effects are often proposed, they are rarely systematically evaluated. This gap underscores the importance of integrating phytochemical standardization with mechanistic and clinical research.

7. Implications for Future Research

To advance the therapeutic potential of *Scutellaria* species, future studies should prioritize standardized extraction protocols, comparative analyses across species, and detailed pharmacokinetic profiling of key compounds. Furthermore, well-designed clinical trials are essential to validate preclinical findings and assess safety, efficacy, and optimal dosing strategies. Expanding research beyond *S. baicalensis* to include underexplored species may also uncover novel bioactive compounds with distinct or complementary mechanisms of action.

8. Synthesis

Collectively, current evidence suggests that *Scutellaria*-derived compounds exert anti-obesity effects through multi-target mechanisms, including inhibition of adipogenesis, modulation of lipid metabolism, suppression of inflammation, and potential regulation of energy expenditure. Nevertheless, the predominance of preclinical data, coupled with methodological inconsistencies and limited clinical validation, underscores the need for a more rigorous and integrative research approach. Addressing these challenges will be essential to fully elucidate the role of *Scutellaria* as a viable source of anti-obesity therapeutics.

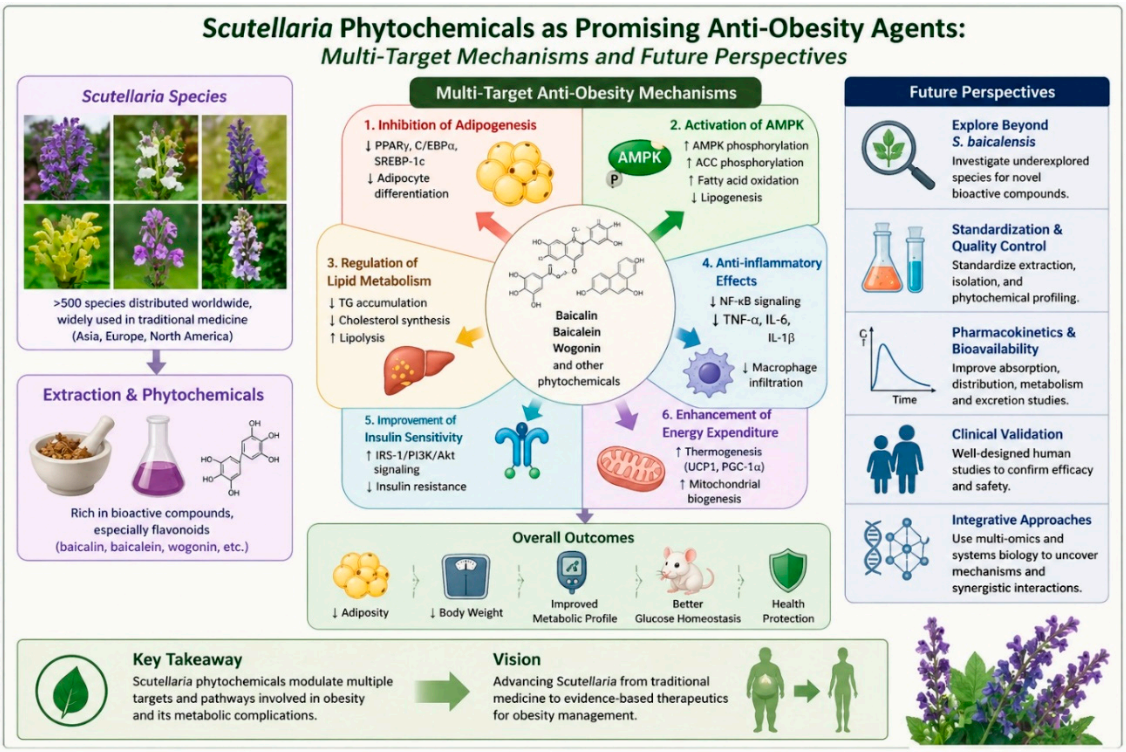

Figure 4. Graphical conclusion and Future perspectives.

9. Conclusions

The genus *Scutellaria* represents a promising yet underutilized source of bioactive compounds with potential applications in obesity management. Accumulating evidence indicates that *Scutellaria*-derived flavonoids, particularly baicalin, baicalein, and wogonin, exert multi-target effects on key pathways involved in obesity pathogenesis, including the regulation of adipogenesis, lipid metabolism, inflammation, and energy homeostasis. These findings support the concept that plant-derived compounds may offer a complementary or alternative approach to conventional anti-obesity therapies.

However, despite encouraging preclinical data, the current body of evidence remains limited by several critical challenges. Research efforts are disproportionately focused on a small number of species, primarily *Scutellaria baicalensis*, while the pharmacological potential of many other species within the genus remains largely unexplored. In addition, methodological inconsistencies, including variability in extraction procedures, compound standardization, and experimental models, hinder cross-study comparability and reproducibility. Critically, the lack of well-designed clinical studies represents a major barrier to translating preclinical findings into therapeutic applications.

Future research should prioritize systematic phytochemical profiling across a broader range of *Scutellaria* species, alongside standardized experimental frameworks to enable more robust comparisons. Elucidation of pharmacokinetic properties, bioavailability, and safety profiles of key compounds is essential to bridge the gap between experimental efficacy and clinical applicability. Moreover, integrative approaches combining phytochemistry, molecular pharmacology, and clinical investigation will be critical for identifying lead compounds and validating their therapeutic potential.

In conclusion, while *Scutellaria* species exhibit considerable promise as sources of anti-obesity agents, their translation into clinically relevant therapies requires a more rigorous, standardized, and multidisciplinary research strategy. Addressing these challenges will be essential to fully realize the therapeutic value of this chemically and biologically diverse genus.

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Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

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