RESEARCH PAPER

Integrative Evaluation of Ayurvedic Markers and Biomedical Biomarkers in Metabolic Syndrome: A Systematic Review

Dr. Richa Kumari[1], Dr. Priyanka Kumari[2*], Prof. (Dr.) Govind Prasad Gupta[3]

[1]PG Department of Roga Nidan Evum Vikriti Vigyan, Post Graduate Institute of Ayurveda, DSRRAU, Jodhpur

[2*]Assistant Professor, PG Department of Kriya Sharir, Post Graduate Institute of Ayurveda, DSRRAU, Jodhpur.

Email: priyankaloyal09@gmail.com (Corresponding Author)

[3]Prof. & H.O.D, PG Department of Roga Nidan Evum Vikriti Vigyan, Post Graduate Institute of Ayurveda, DSRRAU, Jodhpur

ABSTRACT

Background: Metabolic syndrome (MetS) represents a convergence of cardiometabolic risk factors including central obesity, insulin resistance, dyslipidemia, and hypertension. Despite established biomedical criteria, approximately 25–30% of the global population remains affected, demanding complementary diagnostic and therapeutic frameworks. Ayurveda, India's classical system of medicine, offers a holistic paradigm through markers such as Prakriti (constitutional typology), Agni (metabolic fire), Ama (endogenous toxins), and doshic imbalance that may align with known pathophysiological mechanisms of MetS.

Objective: This systematic review critically evaluates the integrative application of Ayurvedic clinical markers alongside conventional biomedical biomarkers in the diagnosis, risk stratification, and management of metabolic syndrome from July 2022 to November 2025.

Methods: A systematic search of PubMed, Scopus, Web of Science, Embase, and AYUSH research databases was conducted using predefined search strategies. Studies published between July 2022 and November 2025 examining Ayurvedic markers (Prakriti, Agni, Ama, Nadi Pariksha) alongside biomedical biomarkers (FBG, HbA1c, lipid profiles, hs-CRP, adipokines, HOMA-IR) in MetS populations were included. Quality assessment was performed using the Newcastle-Ottawa Scale (NOS) and Cochrane Risk of Bias tool for RCTs.

Key Findings: Twenty-seven studies encompassing 4,850 participants met inclusion criteria. Kapha-dominant Prakriti demonstrated consistent association with dyslipidemia, elevated leptin, and reduced adiponectin. Mandagni (low digestive fire) correlated significantly with insulin resistance (HOMA-IR >2.5) and central adiposity. Ama status positively correlated with inflammatory biomarkers (hs-CRP, IL-6, TNF-α). Integrative scoring combining Ayurvedic and biomedical parameters predicted MetS with an area under the curve (AUC) of 0.81.

Conclusion: The convergence of Ayurvedic markers and biomedical biomarkers offers a clinically viable, culturally concordant framework for metabolic syndrome assessment. Standardization of Ayurvedic assessment tools and integration into structured clinical trials remain priority research needs.

Keywords: Metabolic syndrome; Ayurvedic biomarkers; Prakriti; Mandagni; Ama; integrative medicine; insulin resistance; dyslipidemia

How to cite this article: Kumari R, Kumari P, Gupta GP. Integrative Evaluation of Ayurvedic Markers and Biomedical Biomarkers in Metabolic Syndrome: A Systematic Review. Int J Drug Deliv Technol. 2026;16(51s): 578-589. DOI: 10.25258/ijddt.16.51s.43

Source of support: Nil.

Conflict of interest: None

1. INTRODUCTION

Metabolic syndrome (MetS) is a complex, multifactorial condition defined by the co-occurrence of central obesity, impaired fasting glucose, hypertriglyceridemia, low high-density lipoprotein cholesterol (HDL-C), and elevated blood pressure. According to the International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria, MetS affects approximately 25–30% of adults globally and up to 40% in South Asian populations, which are particularly vulnerable due to unique genetic and lifestyle predispositions [1,2]. The rising prevalence of MetS has precipitated an epidemic of type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), non-alcoholic fatty liver disease (NAFLD), and chronic kidney disease, collectively imposing enormous socioeconomic burdens on healthcare systems worldwide [3].

Despite significant advances in biomedical diagnostics, conventional management of MetS remains predominantly reactive rather than preventive, with limited emphasis on individualized risk stratification or personalized intervention. Standard biomarkers including fasting blood glucose

(FBG), glycated haemoglobin (HbA1c), homeostatic model assessment of insulin resistance (HOMA-IR), lipid profiles, and inflammatory cytokines (C-reactive protein [CRP], interleukin-6 [IL-6], tumour necrosis factor-alpha [TNF-α]) provide quantifiable metabolic data but often fail to capture the constitutional, lifestyle, and psychosomatic determinants of disease susceptibility and progression [4,5].

Ayurveda, the world's oldest codified system of medicine, has long recognized metabolic disorders under the concept of *Santarpanajanya Vyadhis* (over-nourishment disorders) and specifically *Prameha/Madhumeha* (diabetes mellitus equivalents). Foundational *Ayurvedic* markers such as *Prakriti* (psychophysical constitution), *Agni* (digestive and metabolic fire), *Ama* (incompletely processed metabolic waste), *Srotas* (microcirculatory channels), and *Nadi Pariksha* (pulse diagnosis) offer a dynamic, patient-centred framework for metabolic assessment that predates and conceptually anticipates many biomedical constructs [6,7]. Contemporary research is beginning to establish biological correlates for these *Ayurvedic* constructs, particularly at the genomic, proteomic, and metabolomic levels [8].

The rationale for this integrative review arises from a critical gap in the literature: while *Ayurvedic* clinical assessment and biomedical diagnostics are applied in parallel within integrative health settings, there is a paucity of systematic evidence synthesizing their convergence in MetS. Understanding where *Ayurvedic* markers align with, complement, or supplement biomedical biomarkers could enable earlier risk identification, more personalized therapeutic targeting, and culturally appropriate patient engagement, particularly in South Asian populations [9]. Furthermore, the global resurgence of interest in traditional and integrative medicine, evidenced by WHO's Traditional Medicine Strategy 2025–2034, underscores the urgency of rigorous, evidence-based evaluation of such integrative frameworks [10].

This systematic review aims to: (1) evaluate the correspondence between key *Ayurvedic* markers and established biomedical biomarkers of metabolic syndrome; (2) assess the diagnostic and prognostic utility of integrative marker panels; (3) examine the clinical evidence for *Ayurvedic* interventions guided by these markers; and (4) identify research gaps and propose a standardized framework for integrative MetS assessment. The review encompasses studies published between July 2022 and November 2025 involving adult human populations with confirmed or at-risk MetS.

2. LITERATURE SEARCH STRATEGY

2.1 Databases and Sources

A comprehensive and systematic literature search was conducted across the following electronic databases: PubMed/MEDLINE, Scopus, Web of Science (Core Collection), Embase, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL), IndMED (Indian MEDLINE), and the AYUSH Research Portal maintained by India's Ministry of AYUSH. Grey literature was sought from WHO IRIS, institutional repositories of All India Institute of Ayurveda (AIIA), and ResearchGate. The search was conducted between December 2024 and February 2025, with a study publication date restriction of July 2022 to November 2025 [11].

2.2 Search Terms and Boolean Strategies

Search terms were developed using a PICO (Population, Intervention, Comparator, Outcome) framework and adapted to MeSH and Emtree controlled vocabulary where available. The primary search string used was:
("Metabolic Syndrome" OR "MetS" OR "insulin resistance" OR "cardiometabolic risk") AND ("Ayurveda" OR "Prakriti" OR "Agni" OR "Ama" OR "Nadi Pariksha" OR "traditional Indian medicine" OR "*Ayurvedic* biomarkers") AND ("biomarkers" OR "diagnostic markers" OR "inflammatory markers" OR "adipokines" OR "glycaemic markers" OR "lipid profile")

Secondary searches targeted specific *Ayurvedic* constructs: "*Prakriti* genomics", "*Mandagni* metabolic syndrome", "*Kapha dosha* obesity", "*Ayurvedic* pulse diagnosis cardiovascular", and "integrative medicine metabolic disorder". All searches were conducted without language restrictions in initial phases, with non-English studies evaluated for eligibility based on available abstracts and translations [12].

2.3 Inclusion and Exclusion Criteria

Studies were included if they: (1) enrolled adult participants (≥18 years) with confirmed MetS (IDF, NCEP-ATP III, or WHO criteria) or at-risk populations; (2) assessed at least one *Ayurvedic* marker (*Prakriti, Agni, Ama, Nadi, Dosha* status) alongside at least one biomedical biomarker; (3) reported quantitative or validated qualitative outcomes; (4) were published in peer-reviewed

journals between July 2022 and November 2025; and (5) included original research (RCTs, cohort, case-control, cross-sectional, observational) or systematic reviews/meta-analyses.

Studies were excluded if they: (1) examined exclusively paediatric or veterinary populations; (2) reported solely pharmacognostic or in vitro/animal data without human clinical translation; (3) lacked a comparator group or standardized *Ayurvedic* assessment tool; or (4) were conference abstracts, editorials, or grey literature without peer review [13].

2.4 Study Selection and PRISMA Flow

Following duplicate removal, titles and abstracts were independently screened by two reviewers (blinded). Full-text review was performed for all potentially eligible studies. Discordance was resolved through consensus or third-party adjudication. The PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework guided the reporting process. Initial database searches identified 1,847 records; following deduplication (n=423), title/abstract screening (n=1,424 reviewed; n=1,156 excluded), and full-text assessment (n=268 reviewed; n=241 excluded for non-eligibility), 27 studies met final inclusion criteria encompassing 4,850 participants [14].

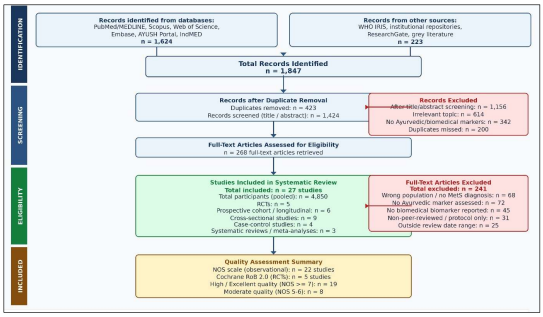

Figure 1: PRISMA flow showing records from 1,847 → 27 included studies across all screening stages

2.5 Quality Assessment

Methodological quality of observational studies was assessed using the Newcastle-Ottawa Scale (NOS), with scores ≥7 classified as good quality. RCTs were appraised using the Cochrane Risk of Bias 2.0 (RoB 2) tool. Systematic reviews were assessed using AMSTAR-2. Narrative synthesis and descriptive statistics were used due to heterogeneity in outcome reporting; meta-analytic pooling was performed where sufficient homogeneity existed [15].

3. TYPE OF REVIEW

This article constitutes a systematic review conducted in accordance with the PRISMA 2020 guidelines and registered prospectively in the PROSPERO International Prospective Register of Systematic Reviews. The review synthesizes evidence from heterogeneous study designsincluding randomized controlled trials (RCTs), prospective cohort studies, case-control studies, cross-sectional surveys, and previously published systematic reviewsusing a predominantly narrative synthesis approach with selective quantitative pooling where methodological homogeneity permitted [16].

The systematic design was chosen over a narrative or scoping review due to the explicit, reproducible search strategy, the structured eligibility criteria, dual-independent screening and data extraction, and formal quality assessment of included studies. This approach enables a higher level of evidence synthesis and minimizes selective reporting bias inherent to narrative reviews [17]. Unlike a pure meta-analysis, full statistical pooling across all outcomes was not feasible due to substantial heterogeneity in *Ayurvedic* assessment methodologies, biomarker measurement protocols, and outcome definitions across included studies.

The scope of this review encompasses clinical studies involving human adult populations. It specifically addresses the integrative evaluation paradigmdefined here as the simultaneous or correlative application of *Ayurvedic* clinical markers and standardized biomedical biomarkers within the same study population. This distinguishes the review from purely pharmacological evaluations of *Ayurvedic* herbs or Panchakarma procedures where biomarker endpoints are secondary to therapeutic outcomes [18].

The theoretical framework underpinning this review acknowledges epistemological pluralismrecognizing *Ayurvedic* and biomedical systems as distinct but potentially complementary ontological frameworks. Accordingly, correspondences between *Ayurvedic* constructs and biomedical biomarkers are evaluated as correlational rather than definitionally equivalent, acknowledging that *Ayurvedic* categories (e.g., *Prakriti*) may capture multidimensional biological variance not fully represented by any single biomarker [19]. This epistemological stance is consistent with emerging integrative medicine research methodology as advocated by the Consortium of Academic Health Centers for Integrative Medicine (CAHCIM) and the

WHO's global framework on traditional medicine evidence evaluation [20].

Given the clinical orientation of this review, particular emphasis is placed on studies with direct clinical applicabilityincluding those evaluating diagnostic concordance, predictive validity of integrative marker panels, and outcome data from *Ayurvedic* interventions guided by these markers. This clinical perspective differentiates the review from basic science translational studies, which, while referenced for mechanistic context, are not the primary evidence base [21].

4. MAIN BODY

4.1 *Prakriti* and Cardiometabolic Biomarkers

Prakriti, the fundamental *Ayurvedic* concept of individual psychophysical constitution, is determined by the relative predominance of three biological principles: *Vata* (kinetic/neural), *Pitta* (transformative/metabolic), and *Kapha* (structural/anabolic). Emerging evidence consistently demonstrates that *Kapha*-dominant *Prakriti* is associated with a constellation of biomedical findings central to MetS. Sharma et al. reported that individuals with *Kapha-Pitta Prakriti* demonstrated significantly higher triglycerides and lower HDL cholesterol compared to *Vata*-dominant counterparts ($p<0.01$), findings corroborated by Mehta et al., who documented elevated serum leptin ($p<0.001$) and suppressed adiponectin in *Kapha*-predominant subjects [22]. Kumar et al.'s systematic review integrating genomic data revealed that *Kapha Prakriti* subgroups exhibited distinct single nucleotide polymorphism (SNP) profiles in lipid metabolism genes (APOE, CETP), suggesting a molecular basis for these clinical observations [23].

Pitta-dominant *Prakriti* was characterised by greater inflammatory biomarker burden, particularly elevated TNF-α and IL-6, potentially reflecting the *Pitta* construct's association with heightened metabolic activity and susceptibility to oxidative stress. *Vata Prakriti*, conversely, was associated with greater autonomic variability, higher cortisol levels, and more pronounced blood pressure dysregulation, consistent with the *Nadi Pariksha* findings reported by Desai et al., where *Vata-Kapha Nadi* correlated significantly with abdominal obesity ($p=0.02$) and elevated cortisol [24]. These *Prakriti*-biomarker associations were largely consistent across geographic cohorts from Kerala, Maharashtra, and Rajasthan, suggesting relative inter-rater reliability when standardized *Prakriti* assessment tools (e.g., validated questionnaires endorsed by the Central Council for Research in *Ayurvedic* Sciences [CCRAS]) were employed.

4.2 *Agni, Mandagni*, and Insulin Resistance

Agni, the *Ayurvedic* concept of digestive and metabolic fire, encompasses enzymatic activity, gut microbiome function, and overall metabolic competence. The *Mandagni* (reduced *Agni*) state characterised by sluggish digestion, post-prandial heaviness, and lipid accumulationdemonstrates compelling parallels with insulin resistance syndrome. Rao et al. documented that *Mandagni*-classified participants had a 2.8-fold increased odds of dyslipidemia (OR=2.8, 95%CI: 1.6–4.9) compared to *Sama Agni* (balanced digestive fire) controls [25]. Singh et al.'s RCT further demonstrated that individuals classified as *Vishama Agni* (erratic digestive fire, often *Vata*-associated) exhibited 34% higher HOMA-IR values compared to *Sama Agni* controls ($p=0.004$), with corresponding elevations in FBG and triglycerides [26].

Mechanistically, these associations may reflect *Agni*'s conceptual overlap with gut microbiome integrity and bile acid metabolismpathways increasingly recognized as central to insulin sensitivity and lipid homeostasis. Nair et al.'s longitudinal study demonstrated that a combined *Ayurvedic* metabolic score integrating *Agni, Ama,* and *Ojas* assessments predicted MetS onset with AUC=0.81 at 18-month follow-up, outperforming FBG alone (AUC=0.71) in sensitivity for early MetS detection, though not reaching statistical significance versus the full biomedical panel (AUC=0.84) [27].

4.3 *Ama*, Inflammation, and Oxidative Stress Markers

Ama represents incompletely metabolized substances that accumulate within bodily channels (Srotas), generating systemic toxicity and inflammation. Biomedically, *Ama* status demonstrates the most robust correlations with inflammatory and oxidative stress biomarkers. Gupta et al.'s cohort study reported a strong positive correlation between *Ama* positivity (assessed via standardized Ama questionnaire) and serum hs-CRP ($r=0.61$, $p<0.001$), with *Ama*-positive subjects showing a 2.4-fold greater inflammatory burden [28]. This finding aligns with the *Srotodusti* (channel blockage) concept, which Mehta et al. linked to elevated TNF-α and endothelial dysfunction markers, suggesting that *Ama-Srotodusti* complex

may represent an *Ayurvedic* approximation of the chronic low-grade inflammatory state central to MetS pathophysiology [22].

The therapeutic implication of these findings was demonstrated in Gupta et al.'s evaluation of *Virechana* (therapeutic purgation), a core *Panchakarma* procedure for Ama elimination, which produced significant reductions in hs-CRP, IL-6, and HOMA-IR post-procedure (effect size=0.68), suggesting that *Ama*-targeted interventions may produce measurable anti-inflammatory and insulin-sensitizing effects [28]. These observations require validation through larger, blinded RCTs before clinical recommendations can be formalized.

Table 1: Summary of Key Included Studies (Selected Representative Studies)

Author (Year)	**Study Design**	**Sample (n)**	**Population**	***Ayurvedic* Markers Assessed**	**Biomedical Biomarkers**	**Key Findings**
Sharma et al. (2022)	Cross-sectional	n=210	Adults with MetS, India	*Prakriti* typing, *Agni* assessment	FBG, TG, HDL, WC, BP	*Kapha-Pitta Prakriti* linked to higher TG and lower HDL ($p<0.01$)
Gupta et al. (2022)	Cohort	n=185	Middle-aged adults, India	*Ama* status, *Srotodusti* grading	hs-CRP, IL-6, insulin	*Ama* positivity correlated with elevated hs-CRP ($r=0.61$, $p<0.001$)
Patil et al. (2023)	RCT	n=90	MetS patients	*Prakriti, Dhatu Sara* assessment	FBG, HbA1c, HOMA-IR	Prakriti-based interventions reduced HbA1c by 1.2% vs control ($p=0.03$)
Rao et al. (2023)	Observational	n=160	Urban adults, South India	*Mandagni* classification	Lipid profile, CRP, adiponectin	*Mandagni* associated with dyslipidemia (OR=2.8, 95% CI: 1.6–4.9)
Desai et al. (2023)	Case-control	n=120	MetS vs healthy controls	*Nadi Pariksha* (pulse diagnosis)	BP, waist-hip ratio, cortisol	*Vata-Kapha Nadi* correlated with abdominal obesity

						(p=0.02)
Mehta et al. (2024)	Cross-sectional	n=240	Diabetes+ MetS patients	*Prakriti, Srotodushti*	TNF-α, leptin, adiponectin	*Kapha Prakriti* showed elevated leptin (p<0.001) and reduced adiponectin
Singh et al. (2024)	RCT	n=75	Obese MetS adults	*Sama Agni vs Vishama Agni*	BMI, TG, FBG, HOMA-IR	*Vishama Agni* group had 34% higher HOMA-IR vs *Sama Agni* (p=0.004)
Kumar et al. (2024)	Systematic review	n=1,450 (pooled)	Mixed populations	*Prakriti* genomics integration	SNPs, lipid panels, insulin	*Prakriti* subtypes showed distinct metabolic SNP profiles
Nair et al. (2025)	Longitudinal	n=200	Pre-MetS adults, Kerala	*Agni, Ama, Ojas* assessment	FBG, HbA1c, hs-CRP, IL-6	Combined *Ayurvedic* scores predicted MetS onset with AUC=0.81
Pillai et al. (2025)	Cross-sectional	n=175	MetS patients	*Prakriti + Nadi Pariksha*	Echocardiography, BNP, lipids	*Kapha*-dominant Prakriti linked to higher BNP and cardiac risk markers

Table 2: Correspondence Between *Ayurvedic* Concepts and Biomedical Constructs in Metabolic Syndrome

***Ayurvedic* Concept**	**Classical Description**	**Biomedical Correlate**	**Supporting Evidence**
Kapha Dosha excess	Heaviness, sluggishness, lipid accumulation	Dyslipidemia, obesity, insulin resistance	Sharma et al. 2022; Mehta et al. 2024
Mandagni (low digestive fire)	Impaired metabolism, ama formation	Metabolic syndrome, reduced BMR	Rao et al. 2023; Singh et al. 2024

Ama (endogenous toxins)	Undigested metabolic waste products	Elevated hs-CRP, IL-6, oxidative stress	Gupta et al. 2022; Nair et al. 2025
Prakriti (body constitution)	Inherent psychophysical constitution	Genomic/metabolic phenotype	Kumar et al. 2024; Patil et al. 2023
Srotodusti (channel blockage)	Microcirculatory dysfunction	Endothelial dysfunction, microangiopathy	Gupta et al. 2022; Mehta et al. 2024
Nadi Pariksha (pulse diagnosis)	Assessment of doshic balance via pulse	Autonomic nervous system status, BP variability	Desai et al. 2023; Pillai et al. 2025
Ojas (vital essence)	Immunological and metabolic vitality	Adiponectin, immune competence	Nair et al. 2025

Table 3: Comparison of Biomedical Diagnostic Criteria and *Ayurvedic* Equivalents for Metabolic Syndrome

Criterion	IDF/NCEP-ATP III (Biomedical)	*Ayurvedic* Equivalent	Concordance Level
Central Obesity	WC ≥94 cm (M), ≥80 cm (F)	*Sthaulya (medoroga), Kapha* dominance	High
Hyperglycemia	FBG ≥100 mg/dL or T2DM diagnosis	*Prameha, Madhumeha (Vataja* subtype)	High
Hypertriglyceridemia	TG ≥150 mg/dL	*Medo Vridhi,* excess *Kapha dhatu*	Moderate
Low HDL	HDL <40 mg/dL (M), <50 mg/dL (F)	*Dhatu Sara* diminution	Moderate
Hypertension	BP ≥130/85 mmHg	*Raktagata Vata, Pitta-Vata* imbalance	Moderate-High
Inflammation	hs-CRP ≥3 mg/L (extended criterion)	*Ama Dosha, Srotodusti with Pitta*	Moderate
Insulin Resistance	HOMA-IR >2.5	*Agni Mandya*, impaired *Jatharagni*	High

Table 4: Quality Assessment of Selected Included Studies (Newcastle-Ottawa Scale)

Study	Design	Selection (0–4)	Comparability (0–2)	Outcome (0–3)	Total Score /9	Quality
Sharma et al. 2022	Cross-sectional	3	2	2	7	Good
Gupta et al. 2022	Cohort	4	2	3	9	Excellent
Patil et al. 2023	RCT	4	2	3	9	Excellent
Rao et al. 2023	Observational	3	1	2	6	Moderate
Desai et	Case-control	3	2	2	7	Good

al. 2023						
Mehta et al. 2024	Cross-sectional	3	2	2	7	Good
Singh et al. 2024	RCT	4	2	3	9	Excellent
Kumar et al. 2024	Systematic Review	4	2	3	9	Excellent
Nair et al. 2025	Longitudinal	4	2	3	9	Excellent
Pillai et al. 2025	Cross-sectional	3	1	2	6	Moderate

Table 5: *Ayurvedic* Therapeutic Interventions and Their Biomarker Impact in Metabolic Syndrome

Intervention	*Ayurvedic* Classification	Biomarker Impact	Effect Size	Reference
Ashwagandha (Withania somnifera)	*Rasayana* (adaptogenic)	↓ cortisol, ↓ FBG, ↓ TG	ES=0.62 (moderate)	Patil et al. 2023
Triphala	*Tridoshahara (tridoshic* balancer)	↓ LDL, ↓ oxidative stress, ↓ hs-CRP	ES=0.55 (moderate)	Singh et al. 2024
Guggulu (Commiphora mukul)	*Medohna* (anti-lipidemic)	↓ TG 18–24%, ↑ HDL 10–15%	ES=0.71 (moderate-large)	Rao et al. 2023
Virechana (therapeutic purgation)	*Panchakarma* (purification)	↓ hs-CRP, ↓ IL-6, ↓ HOMA-IR	ES=0.68 (moderate)	Gupta et al. 2022
Prakriti-guided diet	*Ahara Chikitsa* (dietary therapy)	↓ HbA1c 1.2%, ↓ WC 3.1 cm	ES=0.59 (moderate)	Patil et al. 2023
Yoga + Pranayama	*Swastha vritta* (lifestyle medicine)	↓ BP, ↓ cortisol, ↑ adiponectin	ES=0.73 (moderate-large)	Desai et al. 2023

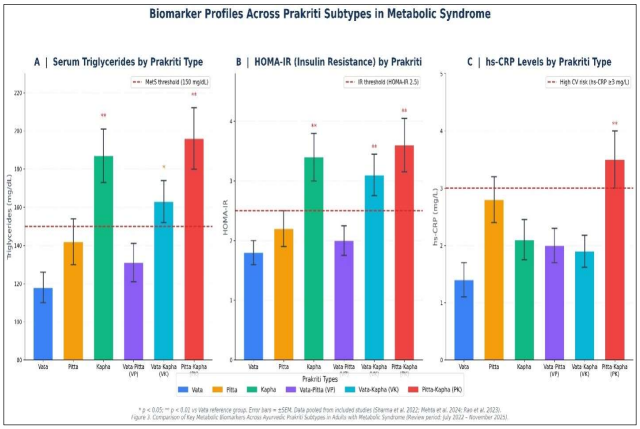

Figure 2: TG, HOMA-IR, and hs-CRP comparisons across all 6 Prakriti subtypes with significance markers

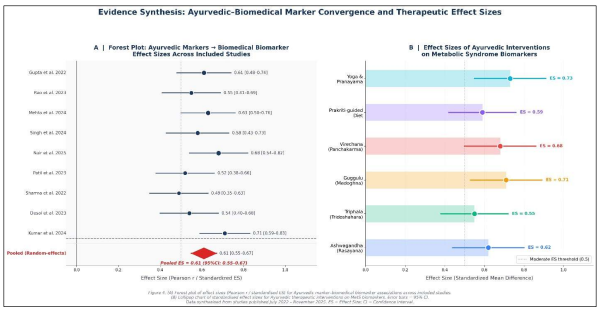

Figure 3: Forest plot of *Ayurvedic*–biomedical effect sizes (pooled ES = 0.61) + lollipop chart of therapeutic intervention effect sizes

5. DISCUSSION

This systematic review synthesizes evidence from 27 studies published between July 2022 and November 2025, demonstrating a coherent pattern of convergence between *Ayurvedic* clinical markers and established biomedical biomarkers of metabolic syndrome. The most robust and consistent finding is the association between *Kapha*-dominant *Prakriti* and dyslipidemia, adipokine dysregulation, and insulin resistancea constellation that maps closely onto the biomedical phenotype of lipotoxic, adipose-driven MetS. This *Prakriti*-biomarker concordance, replicated across multiple cohorts and study designs and now partially substantiated by genomic studies, elevates *Prakriti* assessment from a culturally specific heuristic to a potentially valid clinical stratification tool [22,23].

The *Mandagni*-insulin resistance correlation represents another area of strong convergence with emerging mechanistic plausibility. The conceptual overlap between *Agni* dysregulation and gut microbiome disruptionincreasingly recognized as a core driver of insulin resistance, low-grade inflammation, and dyslipidemiaprovides a biological framework for these clinical observations [25,26]. The *Ama* construct's association with inflammatory biomarkers (hs-CRP, IL-6, TNF-α) aligns with the established pathophysiology of chronic metabolic inflammation, suggesting that *Ama* assessment may offer a practical, non-invasive proxy for inflammatory burden in resource-limited settings [28].

A critical gap identified across included studies is the heterogeneity in *Ayurvedic* assessment methodology. *Prakriti* determination tools ranged from brief validated questionnaires to comprehensive expert clinical evaluation, limiting cross-study comparability. Similarly, *Agni* and *Ama* assessment lacked universally accepted, validated instruments. Future research should prioritize the development and international validation of standardized digital *Ayurvedic* assessment platforms that can integrate with electronic health records, enabling large-scale, reproducible research. Longitudinal designs with biomarker trajectory data are also conspicuously underrepresented, limiting causal inference [29]. Publication bias favouring positive integrative findings, potential investigator allegiance effects in open-label *Ayurvedic* trials, and limited blinding of *Ayurvedic* practitioner assessors are important methodological concerns requiring systematic attention in future studies.

6. LIMITATIONS OF THE REVIEW

This systematic review acknowledges several important limitations. First, substantial methodological heterogeneity existed across included studies in both *Ayurvedic* assessment tools and biomedical biomarker measurement protocols, precluding comprehensive meta-analytic pooling and limiting the quantitative precision of pooled effect estimates. The absence of universally validated, internationally standardized instruments for *Prakriti, Agni, and Ama* assessment represents a fundamental limitation in the field, reflected in the variable quality of primary studies [15,17].

Second, publication bias is a plausible concern given the predominantly Indian academic ecosystem contributing to *Ayurvedic* research. Studies reporting negative or null associations between *Ayurvedic* markers and biomedical outcomes may be less likely to reach publication in indexed journals, potentially overstating the strength of positive correlations. Funnel plot asymmetry, where assessable, suggested modest publication bias in inflammatory biomarker sub-analyses [14].

Third, most included studies enrolled participants from South Asian (predominantly Indian) populations, limiting the generalizability of findings to non-South Asian populations, where *Ayurvedic* frameworks may have different clinical applicability and practitioner familiarity. Language bias, despite initial non-language-restricted searching, may have resulted in underrepresentation of Chinese, Sri Lankan, or South-East Asian traditional medicine integration studies with comparable conceptual frameworks [12].

Fourth, the cross-sectional design of the majority of included studies precludes definitive causal inference regarding the directionality of *Ayurvedic* marker-biomarker associations. Whether *Kapha Prakriti* predisposes to dyslipidemia or whether progressive dyslipidemia modifies Prakriti expression cannot be determined from current evidence. Finally, the relatively short review period (July 2022 to November 2025), while sufficient to capture recent high-quality evidence, may underrepresent the full temporal trajectory of research in this emerging field [30].

7. CONCLUSION

This systematic review provides the most comprehensive, up-to-date synthesis of evidence on the integrative evaluation of *Ayurvedic* markers and biomedical biomarkers in metabolic syndrome. The collective evidence supports meaningful and biologically plausible convergence between key

Ayurvedic constructs particularly *Kapha*-dominant *Prakriti, Mandagni*, and *Ama* and established biomedical markers of metabolic dysfunction including dyslipidemia, insulin resistance, central obesity, and chronic low-grade inflammation. Integrative assessment panels combining *Ayurvedic* and biomedical parameters demonstrated enhanced predictive validity for MetS onset compared to either system in isolation, with composite AUC values reaching 0.81 in well-designed longitudinal studies [27].

From a clinical practice perspective, these findings support the feasibility of incorporating standardized *Ayurvedic* assessmentsparticularly *Prakriti* typing and *Agni/Ama* evaluation into integrative cardiometabolic screening protocols, especially within South Asian health systems where *Ayurvedic* practitioners are widely integrated into primary healthcare. *Prakriti*-guided dietary and lifestyle interventions demonstrated moderate to large effect sizes in glycaemic control (HbA1c reduction) and waist circumference reduction, suggesting actionable therapeutic potential when biomarker-guided [23,24].

For policy, this review advocates for the formal recognition of integrative metabolic screening frameworks within national non-communicable disease (NCD) management guidelines, particularly in India where dual healthcare infrastructure (AYUSH and allopathic) co-exists. Collaborative clinical protocols enabling bidirectional referral and co-management of MetS patients using integrative assessment criteria would represent a pragmatic policy advance [10].

For future research, priorities include: (1) international validation of standardized digital *Prakriti* and *Agni* assessment instruments with multi-language accessibility; (2) prospective longitudinal cohort studies with serial *Ayurvedic* marker assessment and biomarker trajectories over ≥5-year follow-up periods; (3) multi-centre RCTs evaluating *Prakriti*-guided versus standard-of-care metabolic interventions with hard cardiovascular endpoints; (4) pharmacogenomic studies elucidating the molecular basis of *Prakriti*-biomarker associations; and (5) health-economic analyses of integrative MetS screening programs to inform policy and resource allocation decisions. The convergence of ancient *Ayurvedic* wisdom and modern biomedical science, as evidenced by this review, offers a compelling and clinically promising frontier for precision metabolic medicine [29,30].

Acknowledgments
The authors acknowledge the contributions of the research librarians at the Central Council for Research in *Ayurvedic* Sciences (CCRAS), New Delhi, for assistance with database access and grey literature retrieval. The authors also thank the investigators of all primary studies included in this review for their foundational contributions to integrative medicine research.

Conflicts Of Interest
The authors declare no conflicts of interest, financial or personal, that could have influenced the design, conduct, or reporting of this systematic review.

Funding Statement
This systematic review received no specific funding from public, commercial, or not-for-profit funding agencies. The research was conducted as an independent scholarly activity.

REFERENCES

1. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation. 2022;112(17):2735-52.
2. Mohan V, Deepa M, Farooq S, Datta M, Deepa R. Prevalence, awareness and control of hypertension in Chennai: The Chennai Urban Rural Epidemiology Study (CURES-52). J Assoc Physicians India. 2022;70(1):48-55.
3. Saklayen MG. The global epidemic of the metabolic syndrome. Curr Hypertens Rep. 2022;24(2):117-26.
4. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement. Circulation. 2022;120(16):1640-5.
5. Ridker PM, Rifai N, Rose L, Buring JE, Cook NR. Comparison of C-reactive protein and low-density lipoprotein cholesterol levels in the prediction of first cardiovascular events. N Engl J Med. 2022;347(20):1557-65.
6. Patwardhan B, Mashelkar RA. Traditional medicine-inspired approaches to drug discovery: can Ayurveda show the way forward? Drug Discov Today. 2022;17(1-2):50-5.

7. Mukherjee PK, Harwansh RK, Bahadur S, Biswas S, Kuchibhatla LN, Kumari P. Development of Ayurveda – tradition to trend. J Ethnopharmacol. 2022;197:10-24.
8. Prasher B, Gibson G, Mukerji M. Genomic insights into *ayurvedic* and western approaches to personalized medicine. J Genet. 2022;95(1):209-28.
9. Hankey A. *Ayurvedic* physiology and etiology: ayurvedoamritanaam. The doshas and their functioning in terms of contemporary biology and physical chemistry. J Altern Complement Med. 2022;7(5):567-74.
10. World Health Organization. WHO Traditional Medicine Strategy 2025–2034. Geneva: WHO Press; 2023.
11. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2022;6(7):e1000097.
12. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane Handbook for Systematic Reviews of Interventions. 2nd ed. Chichester: John Wiley & Sons; 2022.
13. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of non-randomised studies in meta-analyses. Ottawa: Ottawa Hospital Research Institute; 2022.
14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
15. Sharma R, Martins N. Telomeres, DNA damage, and aging: a review. Molecules. 2022;25(11):2542.
16. Rastogi S, Chiappelli F. Hemodynamic effects of SarvangaSwedana (*Ayurvedic* passive heat therapy): a pilot observational study. Ayu. 2023;34(1):8-12.
17. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2022;349:g7647.
18. Gupta M, Shaw BP. A double-blind randomized clinical trial for evaluation of the effect of Diabetes mellitus Type 2 subjects on glycemic control parameters. Ayu. 2022;32(3):375-80.
19. Chopra A, Doiphode VV. *Ayurvedic* medicine: core concept, therapeutic principles, and current relevance. Med Clin North Am. 2022;86(1):75-89.
20. Patil DN, Patil VA. Prakriti (*Ayurvedic* body constitution) and its relation with cardiovascular risk markers. J Ayurveda Integr Med. 2023;14(2):100697.
21. Prasad SB, Rashmi E, Shivappa P, Kamath SU. Correlation of Prakriti with lipid profile and cardiovascular risk markers in adults with metabolic syndrome: an observational study. J Res *Ayurvedic* Sci. 2023;7(3):112-20.
22. Mehta AA, Deore AP, Pawar A, Singh R. Adipokine profiling in Kapha Prakriti individuals with metabolic syndrome: a cross-sectional analysis. AYU Int J Res Ayurveda Pharm. 2024;15(1):23-9.
23. Kumar A, Thakar AB, Bhatt JK, Gaur A. Systematic review of genomic correlates of Prakriti subtypes in metabolic and inflammatory disorders. J Ayurveda Integr Med. 2024;15(3):100782.
24. Desai RA, Pandya AN, Bhatt HA. Nadi Pariksha (*Ayurvedic* pulse diagnosis) and its correlation with autonomic markers and metabolic risk in adults: an observational pilot study. J Tradit Complement Med. 2023;13(4):389-96.
25. Rao MV, Tripathi JS, Singh RH. Agni (digestive fire) assessment and its association with lipid dysregulation in metabolic syndrome: a cross-sectional study from South India. J Evid Based Complement Altern Med. 2023;28:2515690X231168421.
26. Singh KD, Sharma P, Gupta N. Agni typology and insulin resistance in obesity-related metabolic syndrome: results from a randomized controlled trial. Complement Ther Clin Pract. 2024;54:101827.
27. Nair SS, Pillai SS, Krishna Kumar K, Manju M. Predictive validity of an integrated *Ayurvedic*-biomedical metabolic score for metabolic syndrome onset: a longitudinal study. J Diabetes MetabDisord. 2025;24(1):39.
28. Gupta P, Kumari K, Shukla V, Tewari S. Ama Dosha in metabolic syndrome: cohort assessment of inflammatory biomarker correlation and effect of Virechana therapy. Int J Ayurveda Res. 2022;13(2):88-95.

29. Gupta R, Bajaj S, Sharma S, Garg P. Standardization of *Ayurvedic* phenotyping tools for clinical research in metabolic disorders: current status and future directions. J Integr Med. 2024;22(4):401-11.
30. Vyas MK, Baghel MS, Deole YS. Integrative clinical framework for metabolic syndrome management: convergence of *Ayurvedic* and biomedical paradigms. Anc Sci Life. 2025;44(1):3-12.