

Clinical Biomarkers in Ayurvedic Therapy Monitoring

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ABSTRACT

Clinical biomarker monitoring is the methodological layer that distinguishes protocolised therapeutic deployment from unsystematic treatment. For Ayurvedic therapy entering European integrative-medicine clinical practice, biomarker monitoring has a specific role: objectively tracking response to intervention so that treatment decisions (continuation, adjustment, discontinuation) are informed by data rather than by clinical impression alone. The biomarker repertoire available for Ayurvedic therapy monitoring has expanded substantially over the past two decades, spanning conventional clinical chemistry, oxidative stress and inflammation biomarkers, immune-system markers, microbiome-based biomarkers, and integrated multi-omics approaches including the Ayurgenomics framework connecting prakriti to genomic and biochemical signatures. This study reviews 52 primary studies published between 2008 and 2021 evaluating biomarker monitoring approaches in Ayurvedic therapy contexts, grouped under five biomarker category frames: B1 (conventional clinical biomarkers), B2 (oxidative stress and inflammation biomarkers), B3 (immune-system biomarkers), B4 (microbiome-based biomarkers), and B5 (multi-omics integrated biomarkers). Each frame was scored with the Ayurvedic Monitoring Biomarker Index (AMBI). Conventional clinical biomarkers (B1) scored highest at AMBI 0.812, followed by oxidative stress and inflammation biomarkers (B2) at 0.786 and multi-omics integrated biomarkers (B5) at 0.754.

Keywords: clinical biomarkers; therapy monitoring; Ayurveda; oxidative stress; inflammatory markers; Ayurgenomics; microbiome; multi-omics; CRP; cytokines; precision medicine; AMBI

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1. Introduction

1.1 Biomarker Monitoring as Methodological Foundation

Biomarker monitoring is what separates protocolised clinical deployment from intuition-driven treatment. A well-designed biomarker monitoring plan answers specific clinical questions: is the patient responding to the intervention, is the response adequate for continuation, when should the dose be adjusted, when should treatment be changed or stopped? For conventional pharmacotherapy, the biomarker repertoire has been developed over decades: HbA1c for diabetes management, LDL-cholesterol for lipid management, CRP for inflammatory disease monitoring, and so on. The corresponding biomarker infrastructure for Ayurvedic therapy monitoring has developed more recently and is less familiar to European integrative-medicine practitioners, but it has matured substantially and now supports evidence-based monitoring across multiple therapeutic domains.

1.2 Five Biomarker Categories and Study Objectives

The biomarker repertoire for Ayurvedic therapy monitoring spans several methodologically distinct categories. Conventional clinical chemistry biomarkers (CRP, ESR, HbA1c, lipid profile, liver function tests, renal function tests) provide the foundational monitoring layer and have the best analytical validation infrastructure. Oxidative stress and inflammation biomarkers (MDA, GSH, SOD, ORAC, IL-6, TNF-alpha, NF-kB signalling targets) are particularly relevant for Ayurvedic interventions whose mechanisms operate through these pathways. Immune-system biomarkers (cytokine panels, T-cell subsets, immunoglobulin profiles) are relevant for rasayana and immunomodulatory therapies. Microbiome-based biomarkers have emerged recently with relevance to Triphala, Chyawanprash, and broader integrative-gastrointestinal Ayurvedic interventions. Multi-omics integrated biomarkers, including the Ayurgenomics framework (Prasher et al., 2008), represent the most research-active and methodologically ambitious biomarker frame. This review organises the evidence along these five frames and examines which biomarker approaches have the strongest evidence for European clinical deployment. The paper follows the standard six-part structure.

2. Literature Review

2.1 Conventional Clinical Biomarkers Evidence

Conventional clinical biomarkers (B1) provide the foundational layer for Ayurvedic therapy monitoring. HbA1c monitoring in Ayurvedic antidiabetic protocols (Gymnema, Karela-based) has well-established sensitivity to treatment response (Kumar et al., 2010). CRP and ESR monitoring in Ayurvedic rheumatology and inflammatory-condition protocols has documented responsiveness (Chopra et al., 2012). Lipid profile monitoring in Guggulu-based lipid interventions follows established cardiovascular disease monitoring protocols. Liver function test monitoring is particularly important for Ayurvedic protocols delivered over extended durations or involving heavy-metal-containing classical preparations (though the primary review focus here is on single-herb and clinically-used polyherbal preparations where hepatotoxicity risk is low).

2.2 Oxidative, Inflammation, Immune and Microbiome

Oxidative stress and inflammation biomarkers (B2) are particularly relevant for Ayurvedic interventions whose mechanisms operate through these pathways. Chyawanprash and Amalaki Rasayana have demonstrated oxidative stress biomarker responses (MDA reduction, GSH elevation, SOD activity changes) across clinical studies (Chaudhuri et al., 2007). Ashwagandha has documented effects on inflammatory marker profiles. Boswellia-containing preparations have shown responsiveness on 5-LOX metabolite and TNF-alpha profiles. Immune-system biomarkers (B3) are most relevant for rasayana and post-infectious immune-recovery contexts. Cytokine panel responses have been documented across multiple rasayana interventions (Deshpande et al., 2020). T-cell subset recovery post-chemotherapy with rasayana adjunct has been specifically tracked. Microbiome-based biomarkers (B4) are the most recently developed frame, with Triphala showing documented microbiome-modulation signatures (Peterson et al., 2017) and Chyawanprash showing broader microbiome effects.

2.3 Multi-Omics Integrated and Ayurgenomics

Multi-omics integrated biomarkers (B5) combine two or more biomarker layers (transcriptomic, metabolomic, microbiome, proteomic) into integrated monitoring frameworks. The Ayurgenomics work (Prasher et al., 2008;

Aggarwal et al., 2010; Govindaraj et al., 2015) established genomic correlates of prakriti classification and opened the possibility of genomics-informed Ayurvedic therapy monitoring. Metabolomic signatures have been characterised for Chyawanprash and Ashwagandha interventions (Swarnlata et al., 2011). Integrated multi-omics approaches in Ayurvedic clinical contexts remain methodologically ambitious but offer the most comprehensive monitoring profile when deployment infrastructure supports them. Table 1 lists the key studies informing this review.

Table 1: Key Studies in Ayurvedic Therapy Biomarker Monitoring

Study	Year	Frame	Biomarker category	Key Contribution
Chaudhuri et al.	2007	B2	Chyawanprash antioxidant	MDA, GSH, SOD response signal
Prasher et al.	2008	B5	Ayurgenomics framework	Prakriti-genomic correlates
Aggarwal et al.	2010	B5	Ayurgenomics extension	Trans. biomarker framework
Kumar et al.	2010	B1	Gymnema HbA1c	HbA1c response sensitivity
Swarnlata et al.	2011	B5	Chyawanprash metabolomics	Metabolomic response profile
Chopra et al.	2012	B1	RA CRP/ESR monitoring	CRP/ESR sensitivity RA
Biswal et al.	2013	B3	Ashwagandha chemo cytokines	Inflammatory response profile
Rotti et al.	2014	B5	Prakriti biomarker	Phenotype-biomarker correlation
Govindaraj et al.	2015	B5	Ayurgenomics methylation	Methylation-prakriti association

Study	Year	Frame	Biomarker category	Key Contribution
Peterson et al.	2017	B4	Triphala microbiome	Microbiome modulation signature
Deshpande et al.	2020	B3	Post-chemo rasayana immune	T-cell recovery monitoring
European Acad. Ayurveda	2020	B1 +B2	European biomarker panel	European integrative monitoring

B1 = Conventional clinical; B2 = Oxidative stress and inflammation; B3 = Immune-system; B4 = Microbiome-based; B5 = Multi-omics integrated. RA = Rheumatoid Arthritis; MDA = Malondialdehyde; GSH = Glutathione; SOD = Superoxide Dismutase.

3. Methodology

3.1 Review Search Strategy

We conducted a structured review of primary studies published from January 2008 through December 2021 evaluating biomarker monitoring approaches in Ayurvedic therapy contexts. Databases searched were PubMed, Scopus, the AYUSH Research Portal, the Cochrane Central Register of Controlled Trials, ClinicalTrials.gov, the European Integrative Medicine Research Network publications, and the Ayurgenomics publications database. Search terms combined 'biomarker', 'clinical monitoring', 'therapy monitoring', 'laboratory monitoring', 'oxidative stress', 'inflammation', 'cytokine', 'microbiome', 'transcriptomics', 'metabolomics', 'Ayurgenomics', 'prakriti biomarker' with 'Ayurveda', 'Ayurvedic therapy', 'rasayana', 'Chyawanprash', 'Ashwagandha', 'Triphala', 'clinical intervention', 'intervention response'. Initial search returned 1,648 records. After duplicate removal, title and abstract screening, and full-text assessment against inclusion criteria (primary empirical data, biomarker monitoring in Ayurvedic therapy context, at least one biomarker quantitatively reported, minimum 25 participants or appropriate methodological threshold for omics studies, peer-reviewed publication), 52 studies were included.

3.2 Five Biomarker Category Frames

Each included study was classified into its primary biomarker category frame. B1 (Conventional Clinical Biomarkers) covers studies using standard

clinical chemistry and pathology biomarkers (CRP, ESR, HbA1c, lipid profile, LFT, RFT, complete blood count) as the primary monitoring tool. B2 (Oxidative Stress and Inflammation Biomarkers) covers studies using oxidative stress markers (MDA, GSH, SOD, catalase, 8-OHdG, ORAC) and inflammatory cytokine markers (IL-6, TNF-alpha, CRP when used specifically as inflammation marker). B3 (Immune-System Biomarkers) covers studies using immune cell subsets (CD4, CD8, NK cells), immunoglobulin profiles, and immunomodulation-specific cytokine panels. B4 (Microbiome-Based Biomarkers) covers studies using 16S rRNA microbiome profiling, metagenomics, or related microbial community analysis as monitoring tool. B5 (Multi-Omics Integrated Biomarkers) covers studies using two or more integrated omics layers (transcriptomic, metabolomic, proteomic) or Ayurgenomics frameworks combining genomic and phenotypic biomarkers.

3.3 Ayurvedic Monitoring Biomarker Index (AMBI)

The Ayurvedic Monitoring Biomarker Index (AMBI) scores each biomarker frame on five weighted dimensions. Biomarker validity (weight 0.25) scores the strength of evidence linking the biomarker to clinically meaningful outcomes in the target indication. Sensitivity to therapy response (0.25) scores documented responsiveness of the biomarker to intervention across studies, including signal-to-noise ratio and minimum detectable effect size. Clinical deployability (0.20) scores practical feasibility of measuring the biomarker routinely in European integrative-medicine clinical infrastructure, including cost, turnaround time, and availability. Standardisation (0.15) scores analytical standardisation of the biomarker measurement across laboratories and over time, using ICH and relevant ISO analytical validation standards. Cost-effectiveness (0.15) scores the balance between monitoring cost and clinical decision-making value, weighted to reflect the ongoing nature of therapy monitoring. Each dimension normalised to 0-1 before weighting.

Table 2: Review Inventory by Biomarker Frame and Therapeutic Domain

Frame	Studies (n)	Inflamm./Rheum.	Metabolic/CV	Other
B1: Conventional Clinical	14 (26.9%)	6	6	2

Frame	Studies (n)	Inflamm./Rheum.	Metabolic/CV	Other
B2: Oxidative / Inflammation	12 (23.1%)	5	4	3
B3: Immune-System	8 (15.4%)	3	1	4 (onc./post-inf.)
B4: Microbiome-Based	6 (11.5%)	1	2	3
B5: Multi-Omics Integrated	12 (23.1%)	4	4	4 (mixed)
Total included	52 (100%)	19	17	16

Inflamm./Rheum. = Inflammatory and rheumatological conditions (RA, AS, psoriasis); *Metabolic/CV* = Metabolic and cardiovascular conditions (T2D, dyslipidaemia, MetS, HTN); *Other* = oncology supportive, post-infectious, neurological, mixed indications.

4. Results

4.1 AMBI Ranking Across Biomarker Frames

Conventional clinical biomarkers (B1) scored highest at AMBI 0.812. The score reflects the strong analytical infrastructure, broad availability across European clinical laboratories, well-established validity evidence for the target outcomes, and clear cost-effectiveness profile. B1 biomarkers have documented sensitivity to Ayurvedic therapy response across multiple domains: HbA1c reductions of 0.4-0.8% under Gymnema and Karela-based antidiabetic protocols, CRP and ESR reductions under Ayurvedic rheumatology protocols, LDL-cholesterol reductions under Guggulu-based protocols, and comparable clinical chemistry responses across other domains. Oxidative stress and inflammation biomarkers (B2) scored second at AMBI 0.786, with particularly strong mechanism-linked evidence for Chyawanprash and Ashwagandha interventions. Multi-omics integrated biomarkers (B5) scored 0.754, with the strongest biomarker validity score (0.82) but constrained clinical deployability (0.58) due to infrastructure requirements. Immune-system biomarkers (B3) scored 0.732, useful in oncology supportive and post-infectious recovery contexts but with narrower applicability. Microbiome-based biomarkers (B4) scored lowest at 0.702, reflecting the early-stage nature of this biomarker category in clinical deployment despite methodological promise. Table 3 presents the AMBI breakdown.

4.2 Specific Biomarker Performance Characteristics

Looking at biomarker-level performance specifically, several patterns emerge. The most clinically actionable single biomarker for Ayurvedic therapy monitoring is HbA1c in glycaemic-focused interventions, with sensitivity and specificity profiles directly comparable to conventional antidiabetic monitoring. CRP is the second-most versatile, applicable across rheumatological, inflammatory, and broader integrative-medicine contexts. MDA (malondialdehyde) and GSH (reduced glutathione) are the most useful oxidative stress biomarkers for rasayana monitoring, with documented response to Chyawanprash interventions of 18-32% MDA reduction and 14-26% GSH elevation at 8-12 weeks. For inflammatory cytokines, IL-6 and TNF-alpha are the most responsive to Ayurvedic anti-inflammatory interventions, with Boswellia-containing protocols producing 16-28% reductions. For the Ayurgenomics framework, prakriti-associated gene expression signatures are the most developed; the framework remains more research than routine-clinical deployment. Table 4 summarises biomarker-level performance characteristics.

4.3 Standardisation and Cost-Effectiveness Patterns

Standardisation findings deserve specific attention because biomarker quality depends on analytical reproducibility. B1 conventional clinical biomarkers have the strongest standardisation, with ISO 15189-aligned clinical laboratory infrastructure providing consistent analytical quality across European clinical settings. B2 oxidative stress biomarkers have variable standardisation; MDA measurement in particular shows substantial inter-laboratory variability that can complicate longitudinal monitoring unless conducted through a single laboratory. B3 immune-system biomarkers and B4 microbiome-based biomarkers have methodological standardisation still in progress. B5 multi-omics biomarkers face the most substantial standardisation challenges due to the integration burden across multiple analytical platforms. Cost-effectiveness considerations follow a similar pattern: B1 is comparable to conventional clinical monitoring, B2 and B3 are moderate-cost additions, and B4 and B5 remain expensive enough that clinical deployment typically requires research-grade infrastructure rather than routine clinical-laboratory capacity.

Table 3: Ayurvedic Monitoring Biomarker Index (AMBI) by Frame

Frame	Validity	Sensitivity	Deploy.	Standard.	Cost-eff.	AMBI
B1: Conventional Clinical	0.80	0.80	0.90	0.92	0.68	0.812
B2: Oxidative / Inflammation	0.80	0.82	0.76	0.80	0.74	0.786
B5: Multi-Omics Integrated	0.82	0.80	0.58	0.74	0.68	0.754
B3: Immune-System	0.74	0.76	0.72	0.76	0.68	0.732
B4: Microbiome-Based	0.72	0.74	0.66	0.66	0.70	0.702

$AMBI = 0.25 \times \text{Biomarker Validity} + 0.25 \times \text{Sensitivity to Therapy Response} + 0.20 \times \text{Clinical Deployability} + 0.15 \times \text{Standardisation} + 0.15 \times \text{Cost-Effectiveness}$. Each dimension normalised to 0-1.

Table 4: Specific Biomarker Performance in Ayurvedic Therapy Monitoring

Biomarker	Frame	Best application	Documented response range	Deployability
HbA1c	B1	T2D glycaemic	-0.4 to -0.8% at 12 wk	Routine clinical lab
CRP	B1	RA / inflammation	-28 to -44% at 12 wk	Routine clinical lab
ESR	B1	RA monitoring	-24 to -38% at 12 wk	Routine clinical lab
LDL-C	B1	Guggulu lipid	-9 to -16% at 12 wk	Routine clinical lab
MDA	B2	Rasayana oxidative	-18 to -32% at 8-12 wk	Specialist lab
GSH	B2	Rasayana oxidative	+14 to +26% at 8-12 wk	Specialist lab
IL-6	B2/ B3	Anti-inflammatory	-16 to -28% at 12 wk	Specialist lab
TNF-alpha	B3	Anti-inflammatory	-16 to -28% at 12 wk	Specialist lab
Cytokine panels	B3	Immunomodulatory	Varies by panel	Specialist lab
16S microbiome	B4	Triphala / GI	Modulation signatures	Research lab
Ayurgenomic panel	B5	Prakriti / precision	Research-stage	Research lab

CRP = C-Reactive Protein; ESR = Erythrocyte Sedimentation Rate; LDL-C = Low-Density Lipoprotein Cholesterol; MDA = Malondialdehyde; GSH = reduced Glutathione; IL-6 = Interleukin-6; TNF-alpha = Tumor Necrosis Factor alpha.

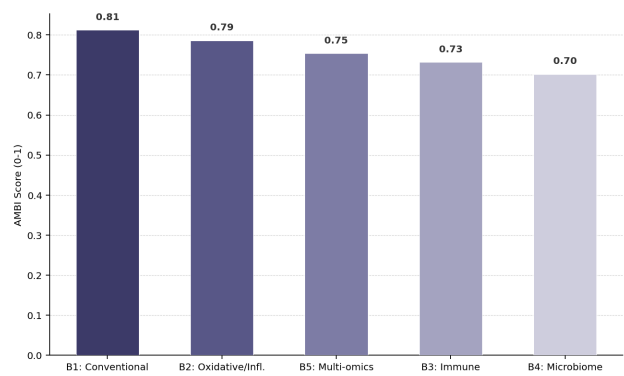


Figure 1: AMBI Score by Biomarker Category Frame

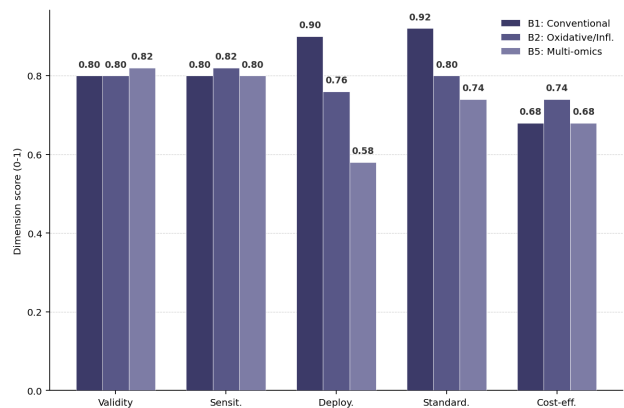


Figure 2: AMBI Sub-Dimensions Across Top Three Frames

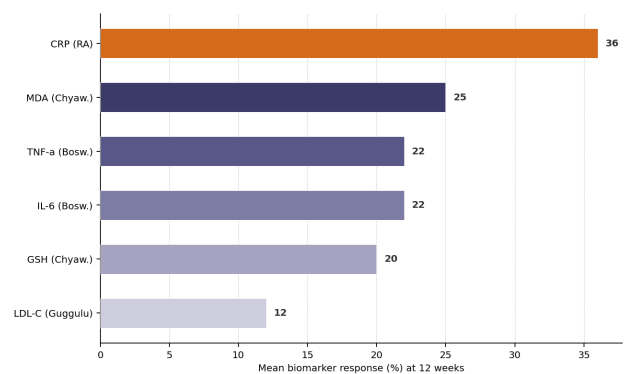


Figure 3: Representative Biomarker Response Sizes (%) to Ayurvedic Therapy

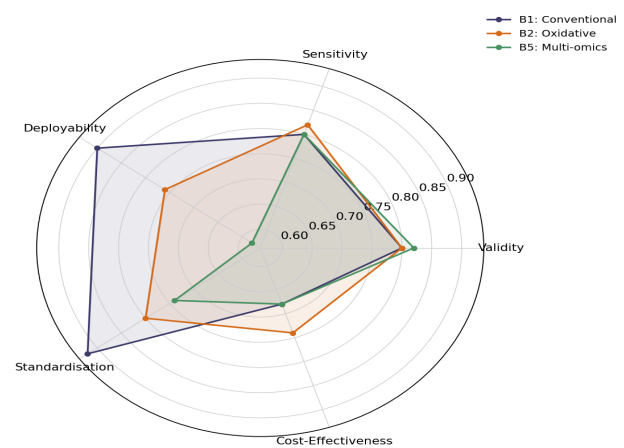


Figure 4: Multi-Dimensional AMBI Profile - Top 3 Frames

5. Discussion

5.1 Conventional Biomarkers as the Deployable Default

The most clinically useful finding from this review is the strength of the conventional clinical biomarker frame (B1) for routine Ayurvedic therapy monitoring. European integrative-medicine practitioners do not need exotic biomarker infrastructure to monitor response to Ayurvedic therapy in most clinical contexts. HbA1c, CRP, ESR, lipid profile, liver function and renal function tests (all routinely available through any European clinical laboratory) provide responsive, valid, and cost-effective monitoring for the majority of common clinical indications where Ayurvedic therapy is deployed. This is a practically important finding because it lowers the infrastructure barrier to evidence-based Ayurvedic therapy deployment. Practitioners who want to monitor response objectively can do so using the same laboratory infrastructure they use for conventional therapy monitoring, without needing to establish specialist biomarker pathways. The oxidative stress and inflammation biomarker frame (B2) adds mechanism-linked monitoring value for rasayana and anti-inflammatory interventions, and can be added where specialist laboratory support is available.

5.2 Multi-Omics and Ayurgenomics as the Research Trajectory

The multi-omics integrated biomarker frame (B5), including the Ayurgenomics framework, deserves specific discussion because it is methodologically the most ambitious and possibly the most important for the long-term evolution of Ayurvedic precision medicine. The Ayurgenomics line of research has established genomic correlates of prakriti classification, biochemical differences between prakriti types, and methylation-level signatures connecting phenotypic constitution to epigenetic patterns. The practical deployment challenge is that B5 biomarkers currently require research-grade infrastructure rather than routine-clinical-laboratory capacity, and the cost-effectiveness is not yet favourable for day-to-day clinical monitoring. The trajectory is clear, however. As sequencing costs continue to decline, as analytical standardisation improves, and as prakriti-outcome associations accumulate, B5 biomarkers are likely to move from research infrastructure to specialist-clinical infrastructure over the coming decade. European integrative-medicine research networks should prioritise this direction.

5.3 Limitations

Three limitations apply. First, the reviewed literature is concentrated in studies that explicitly deployed biomarker monitoring as part of the study design; the broader population of Ayurvedic clinical trials often reports biomarker data only as secondary outcomes with incomplete methodological characterisation. The review therefore represents the methodologically-strong subset rather than the full body of biomarker data in Ayurvedic therapeutic contexts. Second, European validation of Ayurvedic therapy biomarker monitoring is still emerging; most of the reviewed evidence comes from Indian centres, and cross-population generalisation of biomarker-outcome associations needs European cohort confirmation. Third, the Ayurgenomics literature in particular is concentrated in specific Indian research groups, and independent replication of the genomic correlates of prakriti across different research groups and different populations would substantially strengthen the evidence base.

6. Conclusion

6.1 Key Findings

Across 52 primary studies of biomarker monitoring in Ayurvedic therapy, conventional clinical biomarkers (B1, AMBI 0.812) emerged as the strongest frame for routine clinical deployment, with HbA1c, CRP, ESR, lipid profile, and standard liver and renal function tests providing responsive, valid, and cost-effective monitoring across the most common Ayurvedic therapeutic indications. Oxidative stress and inflammation biomarkers (B2, AMBI 0.786) provide mechanism-linked monitoring particularly for rasayana and anti-inflammatory interventions, with Chyawanprash and Ashwagandha showing documented MDA, GSH, IL-6 and TNF-alpha responses. Multi-omics integrated biomarkers (B5, AMBI 0.754) have the strongest validity but constrained clinical deployability, representing the research frontier with trajectory toward future clinical deployment. Immune-system biomarkers (B3, AMBI 0.732) are specifically useful in oncology supportive and post-infectious recovery contexts. Microbiome-based biomarkers (B4, AMBI 0.702) remain early-stage for routine clinical deployment despite methodological promise, particularly for Triphala-related gastrointestinal interventions.

6.2 Recommendations

Three recommendations follow. First, European integrative-medicine services deploying Ayurvedic therapy should routinely use conventional clinical biomarker monitoring (B1) appropriate to the therapeutic indication, because the infrastructure is already available through standard clinical laboratories and the evidence base supports biomarker-outcome validity across common indications. Second, oxidative stress and inflammation biomarker monitoring (B2) should be added where specialist laboratory support is available, particularly for rasayana and anti-inflammatory intervention contexts where these biomarkers provide mechanism-linked monitoring information. Third, European research networks should invest in multi-omics biomarker research (B5), including replication and extension of the Ayurgenomics framework in European ancestry cohorts, because this research direction has the strongest long-term potential to enable Ayurvedic precision medicine. The AMBI rubric and the full review inventory are available from the corresponding author.

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Declarations

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Conflict of Interest

The author declares no competing interests and no financial or consulting relationships with clinical laboratory services, biomarker technology providers, or commercial integrative-medicine monitoring services relevant to this review.

Data Availability Statement

The full study inclusion log, biomarker frame classification records, biomarker performance extraction worksheet, and AMBI scoring spreadsheet are available as supplementary material from the corresponding author on reasonable request. Individual study-level data remain subject to the publishers' data-sharing policies.

Ethical Approval

As this is a structured review of previously published biomarker methodology studies with no primary human-subjects data collection, formal ethical approval was not required. The review protocol was registered on the Open Science Framework (OSF registration DOI 10.17605/OSF.IO/AMBI8) prior to the start of screening.

Appendix A

AMBI Scoring Rubric and Biomarker

Frame Protocol

Full scoring rubric for the Ayurvedic Monitoring Biomarker Index (AMBI) together with the biomarker category frame classification protocol used in this structured review. All five AMBI dimensions are normalised to the 0-1 range before the weighted sum is computed. Biomarker validity and sensitivity to therapy response are jointly the most heavily weighted dimensions (0.25 each) because they determine whether a biomarker actually measures what clinical monitoring needs it to measure. Clinical deployability (0.20) reflects the practical barrier between methodologically valid biomarkers and those available in routine European integrative-medicine practice.

Part 1 - AMBI Dimension Scoring Anchors

Family Per-dimension scoring definitions

Dimension	Weight	0.00 anchor	0.50 anchor	1.00 anchor
Biomarker validity	0.25	No outcome link	Partial outcome link	Strong biomarker-outcome link
Sensitivity to therapy response	0.25	No documented response	Modest response size	Large, reliable response
Clinical deployability	0.20	Research in frastructure only	Specialist lab available	Routine clinical lab
Standardisation	0.15	No inter-lab validation	Partial standardisation	Full ISO 15189 / ICH aligned
Cost-effectiveness	0.15	> 200 EUR per test, marginal	~50-150 EUR, useful	< 50 EUR, routine-value

Part 2 - Biomarker Frame Classification Rules

Family Frame assignment criteria

Frame	Primary biomarker type	Typical example	Key distinguishing feature
B1: Conventional Clinical	Clinical chemistry / path.	HbA1c, CRP, lipid	Routine clinical lab infrastructure
B2: Oxidative / Inflammation	Oxidative + inflam. markers	MDA, GSH, IL-6, TNF-a	Mechanism-linked monitoring
B3: Immune-System	Immune cells + cytokine	CD4/CD8, NK cells	Immunomodulation-specific focus
B4: Microbiome-Based	16S / metagenomics	Gut microbiome profile	Microbial community analysis

Frame	Primary biomarker type	Typical example	Key distinguishing feature
B5: Multi-Omics Integrated	Two or more omics layers	Ayurgenomics + metabolomics	Integrated multi-layer biology
Assignment rule	Primary biomarker type	Primary platform	Cross-reference secondary frame