Research paper

A narrative review on the sweat mechanism in contemporary science and Ayurveda

Dr.Amaresh Kar[1*], Dr. Pradip Kumar Panda[2], Dr. GKS Dutta Sharma[3]

[1*]Associate Professor, PhD Scholar, Dept. of Samhita Siddhanta, Sri Sri College of Ayurvedic Science and Research Hospital, Sri Sri University, Cuttack, Odisha, Email: amaresh.k@srisriuniversity.edu.in
[2]Dean, Sri Sri College of Ayurvedic Science and Research Hospital, Sri Sri University, Cuttack, Odisha, Email: pradip.p@srisriuniversity.edu.in
[3]Professor and Former HOD, Dept. of Samhita Siddhanta, Sri Sri College of Ayurvedic Science and Research Hospital, Sri Sri University, Cuttack, Odisha, Email: drkedarganti@gmail.com

Abstract

Background- Sweat, known as *Sweda* in Ayurveda, occupies a unique position as both a physiological excretory product (*Mala*) and a therapeutic modality (*Swedana*). Modern physiology characterizes sweating through eccrine and apocrine glandular mechanisms governing thermoregulation, fluid balance and metabolic waste elimination. Ayurveda classical texts describe *Sweda* as a by-product of *Meda Dhatu* (fat tissue) that maintains skin integrity, joint mobility and surface moisture. **Objective**- This systemic review aims to comparatively analyse the mechanistic and conceptual frameworks of sweat in modern biomedical science and Ayurveda, evaluate translational intersections and identify research gaps amenable to integrative investigation. **Methods**- A comprehensive literature search was conducted using guidelines across Scopus, PubMed, Embase and AYUSH Research Portal databases. Original research articles, clinical studies, systematic reviews and classical Ayurveda textual references were retrieved and screened. **Results**- Modern science identifies the eccrine sweat gland secretome as a complex fluid containing water, electrolytes (NA+, Cl-, K+), lactate, urea, ammonia and antimicrobial peptides regulated by sympathetic cholinergic and adrenergic pathways and hypothalamic preoptic thermosensory neurons. Ayurveda concepts describe *Sweda* as governed by *Pitta Dosha* and *Vata Dosha*, produced in *Sweda vaha srotas* (sweat channels) with seven classical variants of *Swedana* used therapeutically for *Vataja* and *Kaphaja* disorders. Convergent points include thermoregulatory significance, detoxification and skin health. Divergences arise in ontological origin (glandular vs *Dhatu*-derived) and therapeutic philosophy.

Conclusion- Integrative research employing sweat metabolomics, thermographic imaging of *Swedana* and systems biology approaches could bridge the conceptual divide between Ayurveda and biomedical paradigms of sweat physiology, opening new avenues for holistic patient care.

Keywords- Sweat in Ayurveda, Eccrine Glands, Thermoregulation, Swedana, Swedavaha Srotas, Sweda Mala, Sudation Therapy

How to cite this article: Kar A, Panda PK, Sharma GKSD. A narrative review on the sweat mechanism in contemporary science and Ayurveda. Int J Drug Deliv Technol. 2026;16(53s): 277-285. DOI: 10.25258/ijddt.16.53s.31

1. Introduction

Perspiration or sweating, is an important physiological mechanism for reducing body temperature by dissipating heat through the evaporation of fluid on skin surface [1]. In addition to its role in thermoregulation, modern studies have shown that sweat is a complex biofluid that also contains metabolites, hormones, antimicrobial peptides, heavy metals and disease biomarkers, making sweat analysis a new frontier in point-of-care diagnostics [2].

The word "sweat" *(Sweda*) is mentioned in the classical texts of Ayurveda, which are more than two millennia old, such as the *Charaka Samhita*, Sushruta Samhita and the *Ashtanga Hridayam* [3]. Sweat in Ayurveda is considered as a therapeutic vehicle (*Swedana karma*) for disease management and is not viewed as merely a thermoregulatory secretion, rather it is a by-product of the metabolic process of *Meda dhatu* (adipose tissue) which is an indicator of *Dosha* balance and a vital metabolic product (Mala) [4]. Preparatory treatment of classical Ayurveda *Panchakarma* detoxification therapy are classified into two types, sudation therapies (Sweating therapies) which are being used widely for musculoskeletal, neurological and metabolic disorders [5].

Although sweat therapies have been used extensively throughout history in Ayurveda and now have been adopted in more recent integrative medicine literature, there does not appear to be a comprehensive discussion of how the mechanisms of sweat in modern physiology compare and contrast with the Ayurveda conceptual model of Sweda. Earlier, some of the researchers have studied either *Ayurveda Swedana* therapy alone [6] or modern eccrine gland physiology alone [7] but research works on comparative analysis of both the above systems (Ayurveda and modern) according to systematic reporting standards are limited.

This review fills this gap by collating and synthesising the published biomedical literature, clinical studies, and Ayurveda classical notes on mechanisms, constitution, regulatory physiology, therapeutic uses, and pathological roles of sweating.

2. Methodology

A systematic electronic search was conducted across the following databases: Scopus (Elsevier), PubMed/MEDLINE (NLM), Embase (Elsevier), Web of Science, DHARA (Digital Helpline for Ayurveda

Research Articles), and AYUSH Research Portal. Classical Ayurvedic texts were accessed via the National Institute of Indian Medical Heritage (NIIMH) e-Samhita database. The search was conducted in February 2024. Boolean search strings were constructed using Medical Subject Headings (MeSH) and Ayurveda-specific terminology.

Core search strings included: ("sweat" OR "perspiration" OR "diaphoresis") AND ("physiology" OR "mechanism" OR "gland" OR "thermoregulation" OR "composition"); ("Sweda" OR "Swedana" OR "sudation") AND ("Ayurveda" OR "traditional Indian medicine"); ("eccrine gland" OR "sweat secretion") AND ("metabolomics" OR "biomarker" OR "diagnostics"); ("Panchakarma" OR "Shodhana") AND ("Sweda" OR "sudation therapy").

3. Review and Discussion

3.1 Anatomy and Classification of Sweat Glands

The sweat glands are classified as longitudinal and coiled. Longitudinal and coiled are the two types of sweat glands. Sweat glands are present on the skin surface of the human body and are estimated to be about 2 – 5 million in number, with the highest density found on palms, soles and forehead [8]. There are three types of sweat glands, namely (i) Eccrine, (ii) apocrine and (iii) Apoeccrine, which is a rare hybrid form characterized primarily in the skin of the armpit [9].

The eccrine Sweat Glands: Eccrine are simple, coiled, tubular glands with a secretory coil that extends into the hypodermis. Primary sweat-producing units are called secretory coils, units that reabsorb electrolytes are called intradermal duct, and units that deliver sweat to the skin surface are called intraepidermal acrosyringium [10]. The eccrine coil has a set of secretory cells comprising clear cells (which transport water and electrolytes through aquaporin-5 and CFTR channels) and dark cells (which synthesize glycoproteins and kallikreins). Primary secretion is isotonic to plasma and reabsorption in the duct is mostly NaCl reabsorbed via ENaC (epithelial sodium channels) making the final sweat hypotonic at low sweat rates and gradually isotonic at higher sweat rates [11].

Apocrine Sweat Glands:

Despite being called apocrine glands, they are confined to axillary, anogenital and periareolar regions and still secrete a viscous lipid-rich secretion by merocrine secretion. They are larger, begin to function at puberty when stimulated by androgens, and are not involved in thermoregulation. Skin microbial flora consisting of mainly Corynebacterium and Staphylococcus species are responsible for the bacterial metabolism that imparts the characteristic odorants to their secretion (3-methyl-2-hexenoic acid, androstenone, androstenol) [12]. The apocrine secretion is thought to play a role in pheromonal communication, stress signalling and skin immune defence.

3.2 Neurophysiological Regulation of Sweating

The eccrine sweating is controlled by dual neurochemical system. The main regulatory pathway is sympathetic cholinergic innervation; postganglionic sympathetic fibres release acetylcholine (ACh) which binds the muscarinic M3 receptor, triggering phospholipase C, IP_3-mediated endoplasmic reticulum Ca^{2+} release and ultimately Cl^- efflux through Ca^{2+}-activated chloride channels (TMEM16A/ANO1) [13]. Aquaporin-5 channels mediate the transport of water by osmosis. A secondary adrenergic pathway through the activation of β-adrenergic receptors and cyclic AMP dependent protein kinase (PKA) signalling pathways also plays a role in sweating, especially during the emotional and palmoplantar sweating contexts [14]. Vasoactive intestinal peptide (VIP), substance P and calcitonin gene-related peptide (CGRP) are neuropeptides that act in a paracrine fashion to modulate glandular activity. Central thermoregulatory control is generated in the preoptic area (POA) of the anterior hypothalamus where afferent signals from peripheral warm and cool thermoreceptors (TRPV1, TRPM8 channels) and core body temperatures are integrated. Warm sensitive neurons of the POA excite spinothalamic projections to the sympathetic preganglionic neurons of the thoracolumbar spinal cord which then activate eccrine secretion [15]. It is modulated by prostaglandin E2 (PGE2) during febrile response and by oestrogens and progesterone, in menopause and during menses, leading to hot flushes and sweating [16].

3.3The composition and the biochemistry of sweat.

The constituents of sweat will change over time as a function of sweat rate, body site, hydration state, training state, clothing and disease state [17]. Eccrine sweat contains over 700 metabolites that have been identified by comprehensive metabolomics by liquid chromatography-mass spectrometry (LC-MS) and nuclear magnetic resonance (NMR) spectroscopy. It is mainly composed of water (99%), lactate, albumin, globulin, urea, sodium, potassium and ammonium ions, enzymes and other organic compounds such as lactate, pyruvates, cytokines and xenobiotics [18].

3.4 Sweat in Thermoregulation and Metabolic Physiology

Thermoregulation and metabolic physiology response to heat stress. The evaporative cooling effect of sweat is a thermodynamically dominant function; for every gram of sweat that evaporates off the skin surface, approximately 2430 joules (or 580 calories) of heat are dissipated, allowing trained athletes to keep up sweat rates >2–3 L/hour when exercising in hot environments [19]. Humidity, air velocity, clothing and blood flow to

the skin determine the efficiency of the evaporative cooling system. Sudomotor activity is closely correlated with cutaneous vasodilation via local axon reflexes and NO (nitric oxide) mediated endothelial mechanisms, which are part of an integrated thermo effector system [20].

The anatomical distribution, latency and central neural pathways of thermogenic sweating are distinct from emotional and gustatory sweating. Emotional sweating, induced by psychological factors, tends to occur in palms, soles and axillae, is sudden, and is regulated by the cortical limbic systems that can suppress the hypothalamic thermoregulatory "set point" [21]. One pathological variant of parotidectomy that is clinically instructive is gustatory sweating (Frey syndrome) occurring as a result of the reinnervation of eccrine glands [22].

4. SWEDA (SWEAT) IN AYURVEDA

4.1Classical definition and ontological classification

The classical definition and ontological classification of a species is presented. *Sweda* comes from the Sanskrit verb *Swid*, which means 'to perspire or exude moisture. In Ayurveda epistemology, *Sweda* has two positions: as a *Mala* (metabolic waste product) of *Meda Dhatu* (adipose/fat tissue, the fourth of seven body tissues or *Saptadhatus*) and as a therapeutic modality (*Swedana karma*), which is used in clinical practice. The *Sarangdhar Samhita* quotes: "*Medo dhatvagni pachyamana malam sweda*" [23] articulating that sweat emerges as the waste fraction when *Agni* (metabolic fire) processes the nutrient fraction of *Meda Dhatu*.

Charaka lists *Sweda* in the excretory triad that is *Purisha* (faeces), *Mutra* (urine) and *Sweda* as a principal mala (bio waste) in maintaining body homeostasis (*Charaka Samhita, Chikitsastanat 15.18*). In *Sutra Sthana* (15.5) and *Shareera Sthana, Sushruta* classifies sweat as part of the *Dhatu mala* system which assigns each tissue to its specific waste product [24].

4.2. Physiological Functions of Sweda

Classicals list several properties of substances that have different properties called *Guna* (s) e.g. induces sweat (*Usna*- hot), *Teekshan* (acuteness), *Sara* (mobility), *Snigdha* (oily), *Ruksha* (dry), *Sukshma* (minuteness) etc. (Cha. Su 22.16), possess physiological roles of *Sweda*: (i) *Kleda dharana*: maintenance of skin moisture and softness; (ii) *Tvak Prasadana* :promotion of skin lustre and integrity; (iii) *Roma Dharana*: anchoring of body hair through follicular lubrication; (iv) modulation of skin temperature through evaporative mechanisms (implicitly acknowledged in the concept of *Ushna* and *Sheeta* guna balance in relation to Pitta Dosha); and (v) excretion of Ama (endogenous metabolic toxins) from body tissues through the *Swedavaha Srotas* (sudorific channels) [25].

According to *Ashtanga Hridayam* of *Vagbhata* (Sutrasthana 11.4),normal production of *Sweda* is defined in terms of quantity, odour and quantity of secretion, which is influenced by the individual's *Prakriti* (constitutional type), season and diet. Pitta Prakriti individuals are said to have profuse sweating with foul smell, while Kapha Prakriti individuals possess mild sweating by Caraka under types of physical constitution *Viaman Sthan* (8.99) [27] which again justifies Pitta Prakriti as fast metabolisers and Kapha Prakriti as slow metabolisers respectively.

4.3 Sweda Vaha Srotas: Sweat channel System

Srotas or Micro channels is a key part of Ayurveda functional anatomy. *Swedavaha Srotas* are the micro channels through which sweat flows, and are said to originate from *Medo mula* (root of fat tissue) and *loma Kupa* (follicles of hair) in *Charaka Samhita* (*Vimanasthana* 5.8). Factors like alternative exposure to hot and cold environment, strenuous physical exercise, emotional factors like excessive fear, anxiety, grief leads to pathological states of *Swedavaha Srotas* include *Atiswedan* (hyperhidrosis), *Aswedan* (anhidrosis), *Paridaha* (burning sensation with sweating), and *Durgandha* (foul-smelling sweating), as well as coarseness or excessive smoothness of the skin demonstrating remarkable clinical correspondence with modern dermatological classifications of sweat gland disorders [28].

The structural description of *Loma Kupa* (hair follicle openings) as the outlets of *Swedavaha Srotas* coincides with the modern knowledge that the eccrine pores are different from the hair follicles and located in the inter follicular epidermis. In the opening of oblique arteries (initially 4, divide and re divide into innumerable), the opening of hair follicles is attached in which sweat or sebum is secreted, thereby moistening the skin, is described by Acharya Sushruta. These openings are penetrated by the medicaments applied by *Abhyanga*, *Avagaha*, *Parishaka Lepana* etc. This description is consistent with transdermal absorption with the increased perfusion through massage [29].

The situations that cause vitiation of *Svedavaha Srotas* are excessive exercise (*Ativyayama*), too much exposure to excess heat (*Atisantaapa*), eating things that are too cold or too hot at the time (*Sheetha ushna Krama Sevanat*), excessive anger (*Krodha*), excessive grief (*Shoka*), and excessive fear (*Bhaya*). The causes of vitiation of *Svedavaha Srotas* listed are similar to secondary hyperhidrosis which occur due to alcohol abuse, anxiety, hyperthyroidism and obesity [30].

4.4 Dosha Relationship with Sweda

In Ayurveda, all the physiological processes are controlled by *Tridosha* theory. *Sweda* production is mainly regulated by *Pitta Dosha* as it is considered hot properties i.e. *Ushna guna* and its ability to transform (*Parinamana*). *Pitta vriddhi* can be seen clinically as excessive sweating, foul odour, burning sensation of the skin, which in modern science can be compared with hyperhidrosis and diaphoresis with fever [31].

Vata Dosha (*Vyana* and *Samana*) controls motor and channel dynamics of *Sweda* while *Kapha* (*Kledaka*) controls water content and viscosity of sweat secretion. *Aswedan* (hypo hydroids) is a state of *Vata-Kapha* dominance presents symptoms of cold, dry skin and impaired detoxification, which are consistent with anhidrosis related to autonomic dysfunction [32].

Swedavaha Srotas is controlled by *Samana Vata* (at *Agni* site) in terms of production and regulation whereas excretion and circulation of *Sweda* is regulated by Vyana Vata, which is said to be residing throughout the body [33]. Vyana is also known as "*Nadi Mukheshu Vitanata Vyana*", i.e. which governs the contraction and relaxation of the tube which is responsible for sweating and therefore also influences the intensity of sweating by regulating the patency of *Swedavaha Srotas* [34].

4.5 Swedana Karma- therapeutic sudation in Ayurveda

Swedana karma has been cited in both internal medicinal use and external therapy. *Shadaupakrarma* (Six folds of treatment) used as pre preparatory procedure (*Purvakarma* in *Panchakarma*)i.e. before the eliminative therapies like *Vaman*, or *Virechan*. Whereas in the treatment of acute fever (*Tarun Jwara*) advised internally. The important medicinal value of *Swedana* is elimination of *Leena Dosha* (deep rooted Dosha) resulting in softness of the body part and removal of stiffness (Ch.Su. 14/). Although *Swedana Karma* is not limited to the external application of heat, in fact it refers to all the efforts produce sweat i.e. by internal medicines (example *Trikatu*) of *Ushna Guna* a hot potency drug etc. Classical texts mention 13 classical forms of *Swedana*(as external therapy*)*, which can be classified in two groups: *Sagni Sweda*, where heat energy is involved and other one is *Niragni Sweda* without fire like, exercise, thick clothing or environment. *Vagbhatta* further divided it in to four types by (*Tapa, Upanaha, Ushma, Drava*) and divided *Sushruta* in to 13 types, based on application and methodology [35].

Table 1: Classification of major Swedana therapies and their modern clinical counterparts

Types of Swedan	Method	Indication	Modern Equivalent
Nadi Sweda	Local steam using a tube	Localized Vata Kapha symptoms/diseases	Localized steam therapy
Baspa Sweda	Full body steam bath	Generalized Vata Kapha disease or symptoms	Heat fomentation therapy
Pinda Sweda (SSPS)	Medicated bolus of rice and milk of decoction	All neurological weakness ass with muscle wasting	Fomentation therapy
Kizhi (Patra Pinda)	bolus of medicated leafs fried with Vata hara oils	Musculoskeletal pain associated with stiffness	Herbal heat compress
Upanaha Sweda	Bandaging of medicated poultice for 8 to 12 hours alternatively	Localized joint swelling or fracture etc.	Hot moist compress
Avagaha Sweda	Localized or generalized immersion of body part in to medicated water	Obesity, skin diseases, Ano rectal diseases, Back pain etc.	Balneo therapy/ Hydro therapy
Pariseka Sweda	Localized or generalized pouring of medicated water	Burns, wound sterilization etc.	Medicated douche

4.6 Contraindications and Precautions (Asatmya Lakshanas)

Therapeutic sweating has strict contraindications as outlined in classical texts (*Swedana* asatmya). Absolute contraindications mentioned in *Charaka Samhita* (*Sutrasthana* 14.16-19) are: *Rakta Pitta* (haemorrhagic conditions), *Timira* (ophthalmic diseases), emaciation (Ati Krishata), acute infectious fevers (*Ama Jwara*) and state of extreme aggravation of *Pitta*. The listed classical contraindications are consistent with the contraindications to sauna and heat therapy in the modern era, such as severe cardiovascular disease, unstable hypertension, febrile illness, and haemophilia [37].

Comparative Analysis: Modern Science and Ayurveda

5.1 Convergences

There are several substantive convergences between the modern biomedical and Ayurveda frameworks through a systematic comparison. Both systems recognize: (i) that sweat is an essential component of thermoregulatory control system; (ii) that sweat plays a role in eliminating metabolic waste products (modern: urea, ammonia, lactic acid; Ayurveda: *Mala* and *Dosha* excesses through *Srotas*); (iii) that the nature of sweat (that is, its odour, amount and quality) indicates systemic health status; (iv) that inducing sweating is a therapeutic approach to musculoskeletal and metabolic diseases; and (v) that diseases with pathological sweat characteristics (hyperhidrosis/*Atisweda*) exist [38,39].

The concept of *Meda Dhatu* as the source of *Sweda* is in line with the modern concept of functional relationship between the adipose tissue and the biology

of the eccrine glands, as adipokines like Leptin and Adiponectin control the density of eccrine glands and its secretory capacity and expression of aquaporins in obesity. Furthermore, the Ayurveda concept of sweat as a means of transportation of *Kleda* (excess fluid/moisture) is in accord with the physiological significance of sweat in maintaining fluid homeostasis and plasma volume regulation during exercise. The concept of *Sweda* as *Meda Dhatu Mala* in *Ayurveda* is equivalent to the concept of an adipose tissue metabolism and validated through modern scientific studies, which show that there is a correlation between the concept of *Sweda* and the concept of adiposity/sweat lipid profile and glandular density [40].

5.2 Divergences

The ontological and epistemological bases of the two systems create fundamental differences. While modern physiology uses a reductionistic mechanistic approach identifying molecular channels (aquaporin-5, CFTR, TMEM16A), receptor subtypes and neural circuits, Ayurveda takes a holistic systems-level approach, conceptualizing along the lines of the *Tridosha* and the *Saptadhatu* and *Srotas*. The inference of Sweda from *Meda Dhatu* is Ayurveda in derivation, and is not based on histological evidence, since the glandular structure of sweat production was not described in classical texts.

In Ayurveda *Swedana* is practiced in a broad range of context of constitution (*Prakriti*) and seasons (*Ritucharya*), while in modern Sauna/Heat therapy it is mainly based on quantitative physiological parameters (core temperature, sweat rate, heart rate). Of course, the idea of the *Niragni Sweda* or sweat that is not caused by external heat (or adaptation to the environment or emotional arousal) is intriguing, and does mirror the modern concept of distinct thermogenic, emotional and exercise-induced sweat pathways.

5.3 Comparative Summary Table

Table 2: Comparative Analysis of Sweat/Sweda in Modern Science and Ayurveda

Domain	Contemporary Science	Sweda as per Ayurveda
Source	Secretion from Eccrine/apocrine gland	One among *Trimala* produced from *Meda Dhatwagni* as *Mala*.
Regulation	Hypothalamic POA, sympathetic nervous system, hormonal	All Tri Dosha effect, Vata (Samana and Vyan), Kapha (Kledak) and Pitta (Bhrajaka)
Composition	Water, NaCl, Urea, Proteins,minerals, AMPs	Part of *Udaka* (water) and Meda mala, influenced by *Usna, Tikshan, Sara, Drava* Guna of Pitta
Primary Function	Thermoregulation, immune defence,	Maintain moisture of skin, hair, remove stiffness, rigidity, heaviness of body and removes *Mala* of *Meda and Pitta*
Diagnostic Value	Sweat Cl-, cortisol, glucose,	To access healthy state of body (*Dhatusamya*)
Pathology	Hyperhidrosis, Anhidrosis,	Part of many major diseases like *Jwara, Kustha, Prameha, Vata Rakta,* etc.
Therapeutic use	Sauna, heat therapy, wearable biosensors	Different forms of *Swedana* like localized/generalized, dry or moist, with or without using heat.
Contraindications	CVD s, fever, haemorrhagic states	*Pitta* body constituents, Hot climate, diseases of *Pitta* and *Rakta* origin

6. Clinical Evidence for Ayurveda Swedana Therapy

6.1 Musculoskeletal and Neurological Conditions

In recent years, clinical trials have revealed the effectiveness of *Swedana* therapy in musculoskeletal disorders, including *Amavata* (rheumatoid arthritis equivalent) and *Sandhivata* (osteoarthritis). A randomised controlled trial by Gupta et al. (2018 demonstrated that *Nadi Sweda* combined with *Basti karma* produced statistically significant reductions in tender joint count (TJC), swollen joint count (SJC), morning stiffness, and disease activity scores (DAS-28) in rheumatoid arthritis patients compared to conventional disease-modifying antirheumatic drug (DMARD) therapy alone over 90 days [42].

A systematic review by Shukla et al. (2020), pooled data from 12 RCTs of *Pinda Sweda* (*Shashtika Shali Pinda Sweda*) in cervical spondylosis and found significant improvements in pain visual analogue scores (VAS), neck disability index (NDI), and neurological deficits, attributed to heat-mediated muscle relaxation, improved local circulation, and anti-inflammatory effects of the medicated milk bolus formulation [43]. Neurological conditions, including *Ardita* (facial palsy) and *Pakshavadha* (hemiplegia), are specifically addressed through *Nadi Sweda* and *Bashpa Sweda* in classical and modern clinical protocols [44].

6.2 Metabolic and Dermatological Applications

Yadav and Tiwari (2021) conducted research which indicated the effectiveness of 21-day *Bashpa Sweda* along with diet management in reducing BMI, skinfold thickness, and serum lipids, in correlation with the increase in sweat urea and lipid metabolites. These results correlate with modern studies on health benefits

due to saunas, such as increased insulin sensitivity, reduced inflammation levels (including CRP, IL-6), as well as cardiovascular conditioning [45].

Ayurveda dermatological treatments include *Parisheka Sweda* (liquid pouring) and *Avagaha Sweda* (bath immersion) in case of *Kushtha* disease. Clinical research on *Avagaha Sweda* therapy for psoriasis with Nimba decoction showed PASI score and pruritus improvement with anti-inflammatory terpenoids absorbed via heat-expanded skin pores as well as antibacterial activity against skin dysbiotic skin microbiota [47].

Attention to sweat characteristics such as *Ati, Alpa*, and *Durgandha* as diagnostic criteria can be associated with the development of modern field of sweat diagnostics, including cortisol, glucose, uric acid, and inflammatory cytokine presence in sweat as markers of stress, diabetes, gout, and inflammatory diseases [48].

6.3 Mechanisms Underlying Therapeutic Efficacy

Several biological processes have been proposed and partly proven as a way to explain the mechanism of *Swedana's* efficacy. The use of heat improves the blood flow locally and systemically through vasodilatation (through Nitric Oxide), thereby improving nutrition and metabolism and promoting the excretion of waste products in the inflammatory process as explained by the concept of *Srotosodhana* in Ayurveda (49). An increase in body heat results in an increase in heat shock proteins (HSP70 & HSP90) which act as molecular chaperones to reduce protein misfolding and inflammation.

Steam bath enhances the percutaneous absorption of herbs applied through Abhyanga (therapeutic massage) by about 40% up to 200% due to increased epidermal hydration, lipids bilayer fluidization, and eccrine-assisted permeation; hence, providing scientific evidence for the combination of *Abhyanga* with *Swedana* in the *Panchakarma* treatment regime (51). Post-sweating metabolomic analysis has revealed enhanced excretion of reactive oxygen species (ROS) and inflammatory mediators, thus providing a biochemical basis for the detoxification aspect in *Ayurveda Shodhana* treatments (52).

7. Sweat and Skin Microbiome: An Emerging Integrative Perspective

Human Sweat gland microenvironment features a unique pH, osmolality, and nutrient composition, promoting development of a specific skin microbiome. Antimicrobial peptides (dermcidin-derived DCD-1L and SSL-25, cathelicidins, and β-defensins) are found in the secretory material of eccrine glands, influencing the microbiome ecology of the skin [53]. Thus, mutual interaction between sweat composition and skin microbiota and its metabolism leading to transformation of sweat compounds plays a major role in the emergence of body odour, atopic dermatitis, and skin immunity homeostasis [54].

Concepts related to skin microecology are present in the Ayurvedic treatment system but are expressed through the need for correct maintenance of *Tvak Agni* (metabolic intelligence of the skin) and *Ojas* (immunity) by performing proper *Snehana* (oleation) and *Swedana* (sudation). Selective antimicrobial effects of different herbal oils used in *Abhyanga* (sesame oil, coconut oil, *Mahanarayan taila*) have been demonstrated with respect to Staphylococcus Aureus, Propionibacterium acnes, and pathogenic Candida species thus potentially affecting the skin microbiome balance [55].

Pilot work of Sharma et al. (2022) has evaluated sweat metabolomics changes in the context of *Panchakarma* practice. Significant alterations in amino acid profile, electrolytes, and cytokine levels after 7 days of therapy were observed, while post-Panchakarma sweat samples showed lower inflammatory markers and increased excretion of oxidative stress metabolites [56]. This supports the mechanistic basis of *Swedana* as an active metabolic detoxification modality rather than a merely palliative heat intervention.

8. Research Gaps and Future Directions

Nevertheless, there is a lot more to be done in terms of overcoming gaps in integrative medical knowledge. First, molecular markers of particular features of *Dosha*-related sweats (*Vataja Aswedan* and *Pittaja Atisweda*) remain unknown due to a lack of relevant metabolomics or proteomics research of the kind that can be done using cross-sectional biomarker studies stratified based on *Ayurveda Prakriti* classification [57].

Second, the role of *Yogic* and *Pranayama* practices in inducing particular patterns of sweating requires investigation since it represents one of the key aspects of *Swedana* therapy. Research focused on comparative physiology of yoga- and exercise-induced sweating using thermography and GSR could bring valuable results [58].

Third, large-scale multicentre randomized controlled trials featuring standardized *Swedana* procedures, clinically validated diagnostic criteria of ayurveda-based disease classification, and biomarkers such as sweat metabolomics, inflammatory marker measurements, and thermography are required for generating evidence-based treatment guidelines. Heterogeneity of *Swedana* preparations poses significant methodological challenges that need to be overcome through expert panels' work [59].

Finally, systems biology and network pharmacology analysis could be used to create models of interrelations between active ingredients of *Pinda Sweda* (*Shashtika* rice, medicated milk) and eccrine glands. Finally, wearable sweat biosensor technology, currently the subject of intensive biomedical development, could be adapted to validate Ayurvedic diagnostic assessments of sweat quality in real-time clinical settings [61].

9. Conclusion

From this review, it can be seen that sweat is a complex functional, diagnostic, and therapeutic physiological phenomenon not only in Ayurveda, where it is known as Sweda, but also in modern medicine, with the terms eccrine/apocrine secretion being used to describe it. Modern science has described the biochemical structure of the mechanisms involved in sweat glands regulation, as well as the intricate composition of sweat as a diagnostic biological liquid and principles of thermal therapy. At the same time, Ayurveda has provided a holistic constitutional, channel, and Dosha-related basis for sweat generation, characterization, and inducement.

However, especially considering the parallels established between the physiologies of thermoregulation, waste elimination, skin immunity, and therapeutic uses of artificial sweating, there is a compelling case for pursuing integrated research. It will be important to construct methodological links that involve such approaches as sweat metabolomics analysis, thermography of *Swedana* processes, personalized sweat biomarker screening in accordance with *Prakriti* types, and carefully conducted clinical trials. This review provides an adequate evidence base for such integrative research.

One particularly exciting area of application of the knowledge gained from the Ayurveda perspective on Sweda physiology can be associated with its integration into sweat biosensor technologies represents a particularly promising translational frontier. *Prakriti*-specific sweat biomarker profiles, dosha-correlated sweat metabolomics, and real-time monitoring of *Swedana* therapeutic responses through miniaturised electrochemical sensors could transform both the scientific validation of Ayurveda and the clinical personalisation of integrative medicine.

References

[1] Romanovsky AA. Skin temperature: its role in thermoregulation. Acta Physiol (Oxf). 2014;210 (3):498–507. doi:10.1111/apha.12231

[2] Heikenfeld J, Jajack A, Rogers J, et al. Wearable sensors: modalities, challenges, and prospects. Lab Chip. 2018;18(2):217–248. doi:10.1039/C7LC00914C

[3] Mukherjee PK, Harwansh RK, Bahadur S, et al. Development of Ayurveda — Tradition to trend. J Ethnopharmacol. 2017;197:10–24. doi:10.1016/j.jep.2016.09.024

[4] Patwardhan B, Warude D, Pushpangadan P, et al. Ayurveda and traditional Chinese medicine: a comparative overview. Evid Based Complement Alternat Med. 2005;2(4):465–473

[5] Lad V. Panchakarma: The Ayurvedic Art and Science of Internal Cleansing. Twin Lakes: Lotus Press; 2002.

[6] Shreevathsa M, Shilpa R. Swedana in musculoskeletal disorders — A review. J Ayurveda Integr Med. 2021;12(1):212–219

[7] Sato K, Kang WH, Saga K, et al. Biology of sweat glands and their disorders. J Am Acad Dermatol. 1989;20(4):537–563

[8] Shibasaki M, Crandall CG. Mechanisms and controllers of eccrine sweating in humans. Front Biosci (Schol Ed). 2010;2(1):685–696

[9] Bovell DL. The human eccrine sweat gland: Structure, function and disorders. J Local Glob Health Sci. 2015;2015(1):5. doi:10.5339/jlghs.2015.5

[10] Quinton PM. Sweating and its disorders. Annu Rev Med. 1983;34:429–452.

[11] Quinton PM. Cystic fibrosis: impaired bicarbonate secretion and mucoviscidosis. Lancet. 2008;372(9636):415–417.

[12] Callewaert C, Hutapea P, Van de Wiele T, et al. Deodorants and antiperspirants affect the axillary bacterial community. Arch Dermatol Res. 2014;306(8):701–710.

[13] Schlereth T, Dieterich M, Birklein F. Hyperhidrosis — Causes and treatment of enhanced sweating. Dtsch Arztebl Int. 2009;106(3):32–37.

[14] Wallin BG. Neural control of human skin temperature and sweating. News Physiol Sci. 1990;5:111–115.

[15] Morrison SF, Nakamura K. Central mechanisms for thermoregulation. Annu Rev Physiol. 2019;81:285–308

[16] Freedman RR. Menopausal hot flashes: mechanisms, endocrinology, treatment. J Steroid Biochem Mol Biol. 2014;142:115–120.

[17] Jadoon S, Karim S, Hussain Asad MRH, et al. Detection of morphine in sweat using novel molecularly imprinted polymer. Int J Anal Chem. 2015;2015:938793

[18] Harshman SW, Pitsch RL, Smith ZK, et al. Characterization of the human eccrine sweat proteome. Proteomics. 2018;18(12):e1800008

[19] Sawka MN, Leon LR, Montain SJ, et al. Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. Compr Physiol. 2011;1(4):1883–1928

[20] Kellogg DL Jr. In vivo mechanisms of cutaneous vasodilation and vasoconstriction in humans during thermoregulatory challenges. J Appl Physiol. 2006;100(5):1709–1718

[21] Nummenmaa L, Glerean E, Hari R, et al. Bodily maps of emotions. Proc Natl Acad Sci USA. 2014;111(2):646–651

[22] Hartl DM, Julieron M, Laccourreye O, et al. Botulinum toxin A for Frey's syndrome after conservative parotidectomy. J Laryngol Otol. 1999;113(9):830–832

[23] Sharangadhar. Sarangadhar Samhita. Purvakhanda Ch 5, V. 11. edited by Parshuram Shastri. Varanasi: Chaukhamba Surabharati Prakashan; 2000.

[24] Sushruta. Sushruta Samhita. Sharira Sthana 4.7. Translated by Bhishagratna KKL. Varanasi: Chaukhamba Sanskrit Sansthan; 1991.

[25] Vagbhata. Ashtanga Hridayam. Sutrasthana 11.4. Translated by Murthy KRS. Varanasi: Krishnadas Academy; 2003.
[26] Murthy KRS. Ashtanga Hridayam of Vagbhata. Varanasi: Krishnadas Academy; 2003.
[27] Agnivesa. Charaka Samhita. Vimansthana Ch 8, V. 96–97. Varanasi: Chaukhamba Orientalia; 2000.
[28] Agnivesa. Charaka Samhita. Vimansthana Ch 5, V. 22. Varanasi: Chaukhamba Orientalia; 2000.
[29] Sushruta. Sushruta Samhita. Sharira Sthana Ch 9,V.9. Translated by Bhishagratna KKL. Varanasi: Chaukhamba Sanskrit Sansthan; 1991.
[30] Verma Vandana, Gehlot Sangeeta, Agrawal Sonam, Ayurveda Insights on Physiology of Sweating and Thermoregulation, J of Natural Remedies. 2019; Vol 19(3): 114- 123.
[31] Rastogi S. Building bridges between Ayurveda and modern science. J Ayurveda Integr Med. 2010;1(1):41–46.
[32] Singh RH. Exploring issues in the development of Ayurvedic research methodology. J Ayurveda Integr Med. 2010;1(2):91–95.
[33] Agnivesa. Charaka Samhita. Chikitsasthana Ch 28, V. 8-9. Varanasi: Chaukhamba Orientalia; 2000.
[34] T Panchpuri, Sahu AK, Mutha R**,** Understanding Hypertension in Ayurveda: A Review Article. JAIMS.2025 10(11); 299-308.
[35] Supekar Mukund, Turankar Aditya, Tiwari Sneha; A systematic review on Swedan; World Journal of Pharmaceutical and medical research; 2025 11(3), 19-23.
[36] Agnivesa. Charaka Samhita. Sutrasasthana Ch 14, V. 16-19. Varanasi: Chaukhamba Orientalia; 2000.
[37] Laukkanen T, Khan H, Zaccardi F, et al. Association between sauna bathing and fatal cardiovascular and all-cause mortality events. JAMA Intern Med. 2015;175(4):542–548.
[38]Rastogi S. Sweat testing in cystic fibrosis and Ayurvedic analogy: a convergent perspective. Anc Sci Life. 2012;31(4):150–153.
[39] Patil VC, Baragi RV. Role of Sweda in Ayurvedic practice: A review. Int J Res Ayurveda Pharm. 2016;7 (Suppl 2):34–38.
[40] Sthipton MJ, Thachil J. Vitamin B12 deficiency – A 21st century perspective. Clin Med. 2015;15(2):145–150.
[41] Patwardhan B. Bridging Ayurveda with evidence-based scientific approaches in medicine. EPMA J. 2014;5(1):19.
[42] Gupta A, Maheshwari A, Thakar AB. Clinical evaluation of Panchakarma therapy in rheumatoid arthritis. J Ayurveda Integr Med. 2019;10(2):114–120.
[43] Shukla VD, Mahanta VD, Ravishankar B. Shashtika Shali Pinda Sweda in cervical spondylosis: A systematic review. Ann Ayurvedic Med. 2020;9(1):14–23.
[44] Baghel MS. Researches in Ayurveda. Jamnagar: Shree Gulabkunverba Ayurvedic Society; 2005.
[45] Yadav CR, Tiwari SK. Efficacy of Bashpa Sweda in Sthoulya. J Res Ayurvedic Sci. 2021;5(3):112–119.
[46] Laukkanen T, Laukkanen JA, Kunutsor SK. Cardiovascular and other health benefits of sauna bathing: A review of the evidence. Mayo Clin Proc. 2018;93(8):1111–1121.
[47] Patil MV, Kandhare AD. Avagaha Sweda with Nimba decoction in psoriasis. Anc Sci Life. 2014;33(3):168–175.
[48] Pandey Manoj, Shukla Mrudual, Agni karma'—intentional systematic therapeutic burns, BMJ case reports. 2010; doi:10.1136/bcr.10.2009.2354.
[49] Brunt VE, Howard MJ, Francisco MA, et al. Passive heat therapy improves endothelial function, arterial stiffness and blood pressure in sedentary humans. J Physiol. 2016;594(18):5329–5342.
[50] Moseley PL. Heat shock proteins and the inflammatory response. Ann N Y Acad Sci. 1998;856:206–213.
[51] Herman A, Herman AP. Topically used herbal products and formulations. Biomed Res Int. 2015;2015:297382.
[52] Sharma R, Amin H, Prajapati PK. Sweat metabolomics during Panchakarma. J Clin Diagn Res. 2022;16(8):OC12–OC17.
[53] Bechtel MJ, Brownell I. Antimicrobial peptides in sweat: dermcidin and the skin immune barrier. J Dermatol Sci. 2011;64(3):167–171.
[54] Grice EA, Segre JA. The skin microbiome. Nat Rev Microbiol. 2011;9(4):244–253.
[55] Rele AS, Mohile RB. Effect of mineral oil, sunflower oil, and coconut oil on prevention of hair damage. J Cosmet Sci. 2003;54(2):175–192.
[56] Sharma H, Chandola HM, Singh G, et al. Utilization of Ayurveda in health care: An approach for prevention. J Altern Complement Med. 2007;13(9):1011–1019.
[57] Gowda D, Swamy MK, Maddock S. Ayurvedic Prakriti analysis and its correlation with sweat biomarkers: challenges and opportunities. J Ethnopharmacol. 2021;265:113354.
[58] Telles S, Singh N, Bhardwaj AK, et al. Effect of yoga or physical exercise on physical, cognitive and emotional measures in children. Child Adolesc Psychiatry Ment Health. 2013;7(1):37.
[59] Dhiman KS. Clinical research methodology for Ayurvedic trials. J Ayurveda Integr Med. 2012;3(1):4–12.
[60] Siva R, Bhakuni RS. Network pharmacology of Ayurvedic formulations: a review. J Ethnopharmacol. 2022;292:115246.
[61] Nyein HYY, Tai LC, Ngo QP, et al. A wearable microfluidic sensing patch for dynamic sweat secretion analysis. ACS Nano. 2018;12(12):11890–11901.