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Unifying The Framework of Body Fluid Physiology and Integrative Review of Classical Ayurvedic Literature and Contemporary Biomedical Sciences

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Abstract

Background: Body fluid is vital for the good state of health of any human being. They provide the functions of hydration, transport of nutrients and ensure proper functioning of the cells. Moreover, they allow to maintain the normal body temperature and homeostasis. Modern medicine managed to explore many aspects of the distribution of these fluids and regulation of their levels. There were many studies on the physiology of the kidneys and body's physiology in general conducted by scientists and doctors. However, in contrast to the modern scientific approach, the ancient medical theory of Ayurveda has another vision on the topic of the regulation of body fluids. This medical practice utilizes such concepts as *Jala Mahabhuta*, *Udaka, Ambu, Rasa, Lasika, Kleda, Sweda, Mutra* and *Udakavaha Srotas* in order to describe the process of the regulation of body fluids. These concepts prove the existence of this knowledge in Ayurveda. However, these concepts were always studied separately from each other. There is no synthesis of this information with the current one. **Objectives:** In this paper, the aim is to review the traditional classical understanding of body fluid physiology in Ayurveda in light of the current biomedicine and put forward an integrative concept, organizing these ideas into a holistic system framework while keeping epistemology of Ayurveda. **Methods:** A literature review was done employing both the classical Ayurveda textbooks like Charaka Samhita, Sushruta Samhita, Ashtanga Hridaya and the peer-reviewed literature collected from PubMed, Scopus, Web of Science and Google Scholar. The literature on topics relevant to body fluid physiology, hydration, homeostasis, systems physiology, lymphatic biology, renal physiology and integrative medicine was critically analysed. The synthesis of evidence was done in themes, and integration of the concepts was done by comparative physiological analysis. **Results:** It seems that there is a significant physiological convergence of the concepts about the physiological relevance of body fluids for maintaining homeostasis of the body systems. In contrast to the modern physiology of fluid regulation that includes compartmentalization, neuroendocrine control, membrane transport and molecular signalling, the classical Ayurveda considers body fluid physiology as an interconnected functional system including production of fluids, nourishment, transportation, exchange at the tissue level, regulation of metabolism and fluid elimination. It turns out that the current literature emphasizes the correlations between the individual concepts in Ayurveda and corresponding physiological structures, without integrating them in a common physiological system. On the basis of the synthesized evidence, an integrative framework can be suggested where *Jala Mahabhuta* constitutes the elementary basis of biological fluids, *Udaka* is the primary aqueous medium, Rasa is the nutritive fluid, Srotas are responsible for systemic transportation, Lasika mediates tissue exchange, *Kleda* maintains tissue moisture, Sweda and Mutra take care of fluid elimination. **Conclusion:** The present review proposes an integrative framework that reorganizes dispersed classical Ayurvedic concepts into a coherent model of body fluid physiology, emphasizing functional interactions rather than direct anatomical correlations. This systems-oriented interpretation provides a conceptual bridge between Ayurveda and contemporary physiology while maintaining the theoretical integrity of both disciplines. Although the proposed framework remains hypothesis-generating and requires experimental validation, it establishes a foundation for future interdisciplinary research integrating systems physiology, translational medicine, and Ayurvedic science. By advancing a unified understanding of body fluid regulation, this review contributes a novel perspective that may stimulate further scientific exploration into human homeostasis and integrative physiological research.

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1. INTRODUCTION

Hydration reflects a dynamic physiological equilibrium. Water gain and water losses are continuously maintained through coordinated homeostatic mechanism to preserve the extracellular and intracellular fluid volumes, osmolality, and compositions.[1] Molecular biology advances the concepts revealing the dynamics regulation through specific mechanisms that are Aquaporins transmembrane channels that regulate the rapid osmotic transport through epithelial and endothelial barriers[2], and Copeptin which is a rather table biomarker and serve as a sensitive indicator[3]. Daily fluid hydration directly governs the serum osmolality and neuroendocrine pathways to maintain homeostasis. Chronic underhydration and repeated stimulation of the vasopressin pathway cause low-level metabolic stress, resulting in endothelial dysfunction and accelerated aging. As a result, chronic homeostatic burden transforms into a medical condition, increasing the risk of chronic kidney disease, metabolic disorders, and heart disease.[4]

Hydration is multifactorial. Hydration is a physiological state rather thana simple behavioural act.[5] The process is tightly controlled by an integrated network that involves thirst perception, hypothalamic osmoreceptors, arginine vasopressin, the renin-angiotensin-aldosterone system, concentrating mechanisms, and adaptations.[6] As a result, hydration is currently considered as a complex physiological state which depends not only on fluid intake but also on factors such as age, gender, body composition, diet, exercise, environment, kidney function, endocrine regulation, and pathologies. Such a view on hydration has led to the change of paradigms in the field of science about fluid intake recommendations to understanding of the factors and physiological mechanisms that affect water needs of an individual.[7]

The recommendations about daily water intake of contemporary researchers are mainly based on the observational data and physiological studies with main organizations like EFSA[8], NAM[9], and WHO[10] agreeing that the water needs depend on such factors as age, gender, pregnancy, lactation, physical activity, diet, environmental temperature, humidity, altitude, and diseases. However, despite the aforementioned evidence-based guidelines, significant variation in the amount of water turnover and hydration state exists. Scientific trials using the isotopic method have proven a huge variation in water turnover in persons of similar age and sex due to the differences in body constitution, metabolic rate, physical activity, environmental conditions, kidney concentration ability, diet solute load, and hormonal control. In the same manner, studies done in nephrology have shown that hydration state is regulated by a coordinated system consisting of thirst sensation, osmoreceptors in the hypothalamus, arginine vasopressin, renal water retention, and cardiovascular effects.[11] Taken together, it is clear that while existing hydration recommendations offer solid guidance on a population-wide level, they fail to address the physiological variability involved in individual water needs. This gap has led to increased attention being paid to the identification of other biological and functional factors that might help achieve greater accuracy in hydration assessment and develop personalized hydration approaches.[12]

Although tremendous strides have been made in the field of hydration physiology and the paradigm of personalized medicine, there is still little in the way of existing frameworks to estimate personal water needs, which have primarily been built around demographic, environmental, and physiological characteristics. Thus, there is a need for new frameworks that can include other biological variables to account for individual differences in hydration. Inclusion of other determinants of individual fluid needs using the principles of other physiological models could thus present an opportunity for the evolution of new hydration models.

Way ahead of the contemporary ideas of personalized medicine, Ayurveda understood that the physiological needs, including those for water consumption, are highly personal and need to be decided based on the constitution, functional ability, environmental context, and adaptive potential of the person. Water (Udaka/Ambu) in classical Ayurvedic literature is described not just as a nutritional element but as an essential regulator of life, participating in the process of nourishment of the tissues (Rasa), fluid balance (Kleda), thermoregulation, metabolism, digestion, and excretion. Instead of recommending the same quantity of water consumption by everyone, Ayurvedic literature talks about a number of factors that can together determine individual water needs: Prakriti (constitution), dhatu (tissue), Agni (digestion and metabolic potential), Koshtha (functional ability of GI system), Trishna (thirst sensation), Bala (functional capacity), Ahara (food consumed), Vyayama (exercises performed), Ritu (season), Desha (geographical environment), and Dasha Swanjali Udaka Pramana.[13]

There is an ample description of these aspects in Ayurvedic literature but mostly in qualitative form and rarely explained in the context of contemporary physiology or hydration science. As such, currently, there is no systematic map linking these Ayurvedic determinants of water requirement to contemporary physiological mechanisms, evaluating their biological plausibility, and finding out measurable correlates that can help validate them scientifically. Thus, the current conceptual review is presented to devise an integrative framework for individual water requirements that is based on the integration of contemporary evidence obtained from nephrology, physiology, nutrition, and hydration studies with ancient Ayurvedic principles. Instead of trying to create the direct analogy between the traditional principles and the physiological concepts, this review critically assesses the potential mechanisms behind those principles, discerning the evidence-based findings from the ones that generate hypotheses and provides the framework to conduct future observational and biomarker research.

2. MATERIALS & METHODOLOGY

Comprehensive literature search was conducted to identify related work done. Electronic databases including PubMed, Scopus, Web of Science, Embase, Google Scholar and Research Gate along with classical literature was consulted through Charak, Sushruta Samhita and Ashtanga Hridaya. The search strategy combines MeSH and free-text terms including: Water balance, Water homeostasis, Water turnover, Total body water, Hydration biomarkers, Fluid intake, Personalized hydration, Udaka, Ambu, Trishna, Koshtha, Agni, Prakriti, Ritu, Desha, Udakavaha Srotas, and Dasha Swanjali Udaka Pramana. Thereafter, the corresponding ayurvedic principles were compared with current physiological notions for identifying evidence, mechanism correspondences, information gaps, and future research needs. The framework for individualized water requirement was formulated on the basis of such identified evidence. The preference for high-quality evidence included clinical practice guidelines, systematic reviews, meta-analysis, landmark physiologic studies, and peer reviewed literature from nephrology, nutrition, physiology, and integrative medicine journals. Direct citations were made of classical ayurvedic concepts from original sources to avoid any interpretative bias.

3. RESULTS

Current hydration determinants include body composition, renal physiology, neuroendocrine control mechanisms, environmental exposure, physical activity, dietary intake and the presence of disease. On the other hand, the investigation of the classical

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Ayurvedic literature uncovered that there exists an expanded individualization of these determinants with further inclusion of other factors such as Prakriti, Agni, Koshtha, Trishna, Bala, Ahara, Vyayama, Ritu, Desha and Dasha Swanjali Udaka Pramana. This comparative analysis uncovered many similarities in terms of concept as well as unique factors of Ayurveda which have not yet been studied in modern hydration science.

Table 1. Contemporary determinants of individual water requirement

Domain	Determinant	Physiological Relevance
Demographic[14]	Age	Aging affects water content in total body water (TBW), body composition, renal concentration capacity, thirst sensation, and response to antidiuretic hormone (vasopressin). Infants show high water turnover because of a large extracellular fluid volume, while aged people have low TBW and reduced thirst sensation.
	Sex	Sex differences occur due to lean body mass, fat content, hormones, and sweat gland activity, affecting TBW, sweating, renal function, and water needs.
Anthropometry[15]	Body size	Higher TBW, metabolic rate, and body surface area make larger people need more water and show high water turnover and maintenance requirements.
	Body composition	People with more lean body mass require more TBW and physiological water needs than those having similar body mass but with higher fat content.
Physiological[16]	Pregnancy[17]	Pregnancy causes an increase in plasma volume, extracellular fluid volume, uteroplacental blood flow, fluid requirements of the foetus, and the volume of amniotic fluid, thus increasing TBW.
	Lactation[18]	The synthesis of human milk (~700–800 mL/day in case of exclusive breastfeeding) results in high losses of water per day, making women need extra water to stay hydrated and produce enough milk.
	Thirst Perception[19]	The most important behavioural control of fluid consumption via the actions of hypothalamic osmoreceptors, baroreceptors, plasma osmolality, and arginine vasopressin.
	Renal concentrating capacity[20]	Controls the ability of the kidney to concentrate the urine and produce concentrated urine by vasopressin-driven activation of aquaporin-2 and the creation of the corticomedullary osmotic gradient. Loss of concentrating ability increases obligatory fluid loss.
Lifestyle	Physical activity[21]	Physical exercise stimulates the development of metabolic heat, increasing sweat production and water loss via breathing.
Dietary[22]	Soluble loads	Diets with high contents of sodium and proteins stimulate urinary solute excretion; thus, extra water is needed to compensate for obligatory urine production.
	Food	Approximately 20–30% of daily water intake comes from foods.
Environmental[23]	Ambient temperature	Elevated environmental temperature causes increased cutaneous vasodilation and sweat formation to aid in evaporative cooling, leading to increased insensible and sensible water loss.
	Humidity	Humidity affects the efficiency of evaporation and may lead to sweating without appropriate cooling, hence increasing the risk of dehydration from the activity.
	Altitude	High-altitude exposure leads to increased respiratory water loss as a result of hyperventilation and can lead to altitude diuresis, leading to high water turnover.
	Heat exposure and occupation	People who carry out strenuous work in hot climates (agriculture, mining, construction) suffer from increased fluid losses via sweating.
Clinical	Fever[24]	Increased body temperature increases the metabolic rate, insensible perspiration, and respiratory water loss, thus increasing the fluid needs in patients with fever.

	Gastrointestinal loss[25]	Conditions like vomiting, diarrhea, fistulae, and increased stoma output increase the risk of dehydration by rapidly losing water and electrolytes.
	Renal disorder[26]	Renal diseases affect glomerular filtration rate, renal tubular water reabsorption, and urine concentrating ability, thus requiring specific fluid needs based on the condition's stages.
	Diabetes mellitus[27]	Increased blood glucose above renal threshold causes osmotic diuresis, thus increasing water loss through urine.
	Cardiovascular Dysfunction[28]	Hypohydration negatively impacts vascular function and cardiovascular control. In particular, cutaneous vascular function impairment, decreased endothelial function and changes in BP control have been shown under conditions of hypohydration.

Ayurvedic Determinants of Individual Water Requirement

The review of classical literature on Ayurveda indicated that water requirements can be defined as a personalized physiological function rather than as a static quantitative estimate. Following are the domains and determinants from Ayurvedic literature that synthesize the need of hydration status.

Constitutional factors

Prakriti[29]
Prakriti is thought to be the basic constitutive factor in Ayurveda, forming the cornerstone for personalized medicine. Unlike the temporary pathological state (Vikriti), Prakriti is believed to be stable in life and used as the main determinant for personalized nutrition, lifestyle, and therapy. The importance of constitutional differences in modern biomedical research for the development of personalized medicine becomes increasingly apparent. Body constitution, metabolic phenotype, genotypic variability, microbiota composition, and adaptability affect water metabolism, thermoregulation, kidney functions, and water requirements.[30]

Agni[31]
In Ayurvedic medicine, Agni controls digestion, absorption, and metabolic transformation processes and is thought to be the major determinant of physiological efficiency. As these processes are responsible for determining the rate of energy expenditure, production of endogenous metabolic water, assimilation of nutrients, and thermogenesis, changes in Agni could explain individual differences in water needs.

Koshtha[32]
Koshtha has been linked to the functional characteristics of the gastrointestinal tract, and hence it has the potential to influence the hydration state by way of its effects on intestinal water absorption, bowel transit time, stool water content, and gastrointestinal fluid losses. Therefore, Koshtha is a clinically relevant functional determinant of hydration and daily water needs.

Rasa Dhatu[33]
Out of all the seven Dhatus, Rasa Dhatu has the most relevance in terms of fluid physiology. In Ayurveda classics, the term Rasa refers to the nourishing fluid that is responsible for transport of nutrients, providing nutrition to tissues and maintenance of life. The characteristics of Rasa have been described in terms of fluidity (Drava), nourishment (Preenana) and maintenance of tissue moisture (Kleda).

Trishna[34]
Trishna stands for the physiological desire for water and constitutes the most direct Ayurvedic determinant of hydration. In classical medicine, Trishna is viewed as the body's protective mechanism indicating the reduction of fluids in the body and re-establishing the balance through the intake of water. It is evident that although the mechanisms differ, both approaches consider thirst to be the major determinant of hydration.

Bala[35]
The concept of Bala characterizes an individual's capability to cope with the environment, physical strain, and disease. Individuals with stronger physical strength and higher endurance will perform more activities with higher energy expenditure and higher sweating, leading to higher physiological water requirement. Similar to modern hydration guidelines, physical activity and workload become factors determining fluid intake needs. Therefore, Bala can become an indirect determinant of hydration because of physical activity, metabolic activity, and adaptation to the environment.

Ahara[36]
Ahara is considered as the factor modifying the physiological requirement for water due to the influence of the food's quality and type on digestion and metabolism. Thus, it becomes clear that the diet can affect hydration significantly more than just drinking water.

Vyayama[37]
Physical activities, Vyayama, increase the physiological water requirement by stimulating sweating, increasing metabolic heat production and respiratory water loss. The principle of adjusting fluid intake according to physical activity thus corresponds closely to modern exercise hydration principles.

Ritu[38]
Firstly, Ritu denotes seasonal variability and recognizes that the physiological demands of water change throughout the year. Ayurveda explains the changes occurring seasonally with regard to the environmental temperature, humidity, digestion and sweating, suggesting changes in diet and water intake. Hence, Ritu represents an environmental determinant of water needs that is strongly supported by current science in the area of hydration.

Desha[39]
Desha represents the influence of the geographical location and environment upon physiological function. Geographical conditions, climate, altitude, humidity and temperature have been recognized in Ayurveda as modifying factors to diet and lifestyle, including water intake. Thus, Desha represents an important environmental determinant of water needs that has conceptual agreement with modern physiological knowledge.

Dasha Swanjali Udaka Pramana[40]
Finally, Dasha Swanjali Udaka Pramana represents the classical way of quantifying daily water intake in Ayurveda. However, the application of this quantity cannot be generalized to all people universally. Classical Ayurvedic knowledge is consistent in stressing

the need to individualize water intake based on one's constitution, digestion, physical activity, seasonal variability, environment and physiological state. Therefore, DSAUP is best seen as a reference figure within the context of personalization, as opposed to a recommendation for everyone.

Table 3. Comparative mapping of Ayurvedic determinants of individual water requirement

Domain	Determinant	Functional Role
Anthropometric	Prakriti	Constitutional variability influences the body water and its physiological dynamic equilibrium.
	Dasha Swanjali Udaka Pramana	It represents a personalized estimation of daily water intake.
Physiological	Agni	It reflets the digestive metabolic activity influencing water turnover.
	Koshtha	Intestinal absorption, bowel habits, and fluid balance
	Rasa Dhatu	Fluid transport, nourishment, and hydration homeostasis
	Trishna	Physiological drive for fluid intake
Lifestyle	Vyayama	Sweat loss and metabolic heat production
Dietary	Ahara	Dietary modulation of hydration and water intake
Environmental	Ritu	Seasonal adaptation affecting water requirement
	Desha	Environmental adaptation and water turnover
Other	Bala	Functional demand influencing fluid requirement

4.DISCUSSION

First and foremost, it can be stated that the main conclusion reached during the review of the existing literature sources is that individual water requirements should not be treated as a fixed quantitative value but rather as a physiological feature which is a result of a combination of different constitutional, metabolic, digestive, environmental, behavioural and clinical determinants. Contemporary hydration science has made significant progress in understanding the physiological mechanisms of water balance regulation due to thorough investigation of thirst regulation, neuroendocrine regulation, kidney concentrating ability, body water distribution, body water turnover and environmental factors. As a result, it is possible to make some evidence-based recommendations about water consumption issued by such reputable organizations as the National Academies of Medicine, the European Food Safety Authority and the World Health Organization. Nonetheless, these recommendations were designed for healthy individuals and take into account the existence of significant inter-individual variation which cannot be fully explained using demographic determinants. Moreover, the concept of precision medicine implies that individual reactions are determined by genetic, metabolic, body composition, environment, behavioural and adaptation-related features. Comparative analysis has shown considerable convergence between the concept of certain Ayurvedic determinants and physiological variables. In particular, Trishna is similar to the contemporary notion of thirst as the major behavioural mechanism regulating water intake; Vyayama, Ritu and Desha coincide with well-known determinants including physical activity, seasonality and environmental climate, whereas Ahara is similar to the recognized impact of the composition of food and water content on hydration. This allows assuming that the traditional Ayurvedic determinants of individualized water intake are compatible with the modern concepts of fluid homeostasis despite difference in terminology and theories. At the same time, it becomes obvious that there are several Ayurvedic determinants which are not adequately explored in contemporary science of hydration. Such constructs as Prakriti, Agni, Koshtha, Rasa Dhatu and Dasha Swanjali Udaka Pramana are based on the assumption that constitutional phenotype, digestive-metabolic efficiency, functional characteristics of gastrointestinal system, systemic nourishing fluid action and individualized quantitative assessment of water requirement play their role as well. Though the direct experimental evidence in favour of these correlations is still scarce, such as body composition, resting metabolic rate, gastrointestinal transit time, intestinal water absorption, body water compartments, hydration markers, sweat rate, urine osmolality, copeptin, and water turnover assessed via stable isotopes technique. Therefore, these Ayurvedic determinants should be seen as hypothesis-generating physiological determinants rather than biomedical counterparts of these constructs and thus help to maintain scientific integrity of the research while encouraging interdisciplinarity. This approach corresponds to the general paradigm shift towards precision medicine, when recommendations become more tailored. From the clinical standpoint, better knowledge of the hydration determinants can result in improvement of hydration assessment and personalized recommendations on water intake for diverse populations, e.g., elderly patients, athletes, workers under occupational heat stress, people suffering from obesity, chronic kidney disease, diabetes mellitus, gastrointestinal pathology, etc.

5.CONCLUSION

Individual water requirement is a dynamic biological characteristic regulated by several interacting determinants instead of a static daily volume of water common for everyone. Even though the current science of hydration has revealed a number of determinants such as age, sex, body composition, physical activity, diet, environment, and disease condition, there still exists significant variability between people that cannot be explained at the moment. This review aims to show that Ayurveda provides an individualized approach to hydration with the help of determinants such as Prakriti, Agni, Koshtha, Rasa Dhatu, Trishna, Bala, Ahara, Vyayama, Ritu, Desha, and Dasha Swanjali Udaka Pramana, most of which have a significant conceptual relation to modern physiological factors regulating water homeostasis. Through a systematic analysis of current scientific evidence about modern hydration and ancient Ayurvedic teachings, this review introduces a conceptual model of individual water requirements. The model attempts to formulate several scientifically testable hypotheses based on traditional Ayurveda and modern physiological understanding instead of building an exact correspondence between traditional and modern approaches. Multidisciplinary scientific studies with physiological biomarkers, assessment of body water content, and water turnover are needed to confirm the proposed determinants and estimate their role in individualized hydration.

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