

Knowledge, Attitudes, and Practices Toward Hydration and Herbal Beverage Consumption Among Indian College Students

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Abstract

India's functional beverage landscape has transitioned from a peripheral wellness niche into a multi-billion-dollar commercial domain, growing at a compound annual rate exceeding 11.7% and projected to surpass USD 7.36 billion by 2030. College students aged 18–25 years occupy the demographic frontline of this transformation, simultaneously navigating globally marketed synthetic energy drinks, premium imported electrolyte formulations, and the Ayurvedic traditions embedded in their cultural inheritance. Despite accelerating consumption, structured assessment of what this population actually knows, believes, and does regarding hydration and functional beverages remains strikingly underdeveloped in the Indian scientific literature. This comprehensive narrative review critically examines the Knowledge, Attitudes, and Practices (KAP) of Indian college students toward hydration and herbal drink consumption. It further presents six original research gaps identified through systematic comparative analysis of commercial beverage formulations, synthesises pharmacological evidence for traditional Ayurvedic alternatives, and proposes a multidimensional intervention framework designed to bridge the identified KAP deficits. A PRISMA-informed systematic literature search was conducted across PubMed/MEDLINE, Scopus, and Google Scholar covering peer-reviewed publications from January 2010 to March 2025. Commercial beverage formulations were subjected to a physiological comparator analysis against established sweat-replacement standards. Grey literature including FSSAI regulatory circulars, Ministry of AYUSH reports, and validated market intelligence databases were incorporated. A total of 150 references were reviewed and included following application of explicit inclusion and exclusion criteria. Six original research gaps were identified through formulation analysis: (1) an electrolyte inversion problem, whereby market-dominant beverages prioritise potassium over sodium despite sodium constituting the primary ion lost in sweat; (2) a sugar paradox, in which several beverages contain 10–12 g of sugar per 100 ml — well above the 4 g/100 ml ceiling for isotonic absorption rendering them paradoxically anti-hydrating at high concentration; (3) a pricing inequity gap, where imported premium brands deliver inferior electrolyte profiles at five to ten times the cost of indigenous alternatives; (4) the complete absence of any commercially scaled herbal-synthetic hybrid beverage in the Indian market that integrates clinically dosed Ayurvedic adaptogens with physiologically balanced electrolytes; (5) a regulatory visibility gap in which no mandatory front-of-pack isotonicity or electrolyte-ratio disclosure exists; and (6) a KAP-literacy disconnect where students recognise herbal ingredient names without comprehending pharmacologically effective doses, bioavailability, or safety thresholds. India currently lacks a finest-in-class hydration beverage that meaningfully integrates herbal and synthetic traditions within a clinically defensible, affordably priced, and regulatory-compliant formulation. Closing this market and knowledge gap demands coordinated action across public health education, product innovation, and regulatory reform with the college student demographic serving as the strategic focus of intervention.

Keywords: KAP study; hydration; herbal beverages; Ayurveda; Indian college students; functional beverages; electrolyte formulation; sodium; FSSAI; energy drinks; Ashwagandha; Moringa; nutraceutical; market gap analysis

How To Cite This Article: Singh T, Khara K, Singh A, Sharma D. Knowledge, Attitudes, And Practices Toward Hydration And Herbal Beverage Consumption Among Indian College Students. *Int J Drug Deliv Technol.* 2026;16(26s):675-691. Doi: 10.25258/ijddt.16.26s.73

1. Introduction

The Indian beverage sector has entered an era of structural transformation that is simultaneously economic, cultural,

and epidemiological in character. What was once a market defined by the dominance of carbonated colas and sweetened fruit drinks has fractured into a heterogeneous

landscape of functional hydration products, electrolyte formulations, adaptogen shots, probiotic tonics, protein beverages, and energy stimulants. By the end of 2024, the Indian health drinks market was valued at approximately USD 9.63 billion, with projections placing it above USD 28 billion by 2033 and registering a compound annual growth rate of 11.81%.^{1,2} This trajectory is not merely commercial; it carries significant public health dimensions, because the beverages that 400 million young Indians choose to consume through their most physiologically active decade will influence their metabolic trajectories for decades beyond.

At the centrepiece of this unfolding transition stands the Indian college student a consumer between the ages of 18 and 25 who is simultaneously one of the beverage industry's most vigorously courted targets and one of public health's most analytically neglected populations. This individual lives at a uniquely pressured intersection: subjected to examination-driven cortisol spikes, thermal dehydration from India's demanding climate, social media streams curated by sponsored wellness influencers, campus canteens stocked primarily with the brands possessing the largest distribution budgets, and inherited cultural wisdom that reaches for turmeric and ginger at the first sign of fatigue. Within this environment, every beverage decision is simultaneously a health decision, a financial decision, and a social decision — yet it is almost never an informed decision in any pharmacologically meaningful sense.^{3,4}

The Knowledge, Attitudes, and Practices (KAP) framework was originally developed as an epidemiological diagnostic instrument for infectious disease surveillance, but its analytical architecture mapping the tripartite gap between what people know, what they believe, and what they actually do has proven exceptionally productive when extended to chronic disease prevention, dietary behaviour, and consumer health literacy.⁵ When applied to beverage consumption among Indian college students, the KAP framework yields a finding that is as consistent as it is concerning: awareness of health importance is broad; functional literacy is shallow; attitude toward healthier options is generally positive but commercially fragile; and actual practice is determined by structural convenience, economic constraint, and peer normalisation rather than by any genuine understanding of hydration physiology or herbal pharmacology.^{6,7}

This review emerges from a recognition that the existing literature on Indian youth beverage consumption has largely confined itself to documenting the problem — elevated energy drink uptake, carbonated beverage prevalence, inadequate water intake — without engaging rigorously with the formulation-level analysis necessary to explain why the commercial alternatives currently available are inadequate, or with the market-level analysis necessary to identify what does not yet exist in the Indian functional beverage space. The six original research gaps presented in this paper represent the primary scholarly contribution of

this work: a detailed, evidence-anchored critique of what the Indian beverage market is currently failing to provide and why this failure has direct consequences for the health of one of its largest and most commercially engaged consumer segments.

The review proceeds through a structured narrative that covers: (1) a detailed methodological account of the literature synthesis; (2) an assessment of KAP domains across the Indian college student population; (3) a comparative physiological analysis of commercial beverage formulations; (4) the six original research gaps; (5) the pharmacological evidence base for Ayurvedic herbal alternatives; (6) the regulatory landscape and its implications; (7) a strategic multidimensional intervention framework; and (8) a forward-looking discussion of what a genuinely optimal Indian functional hydration beverage might look like and the structural steps required to bring it to market.

2. Methodology

2.1 Study Design and Search Strategy

This work was designed and conducted as a comprehensive narrative review, structured in alignment with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidance to the extent applicable to narrative synthesis. The review did not undertake quantitative meta-analysis given the heterogeneity of study designs, populations, and outcome measures across the included literature; however, systematic search and screening procedures were applied to ensure reproducibility and comprehensiveness of the evidence base.

Literature searches were conducted across three primary academic databases PubMed/MEDLINE, Scopus, and Google Scholar with supplemental searches in institutional repositories and grey literature databases. The search window covered January 2010 to March 2025, with preferential weighting applied to publications from 2018 onward to reflect contemporary market conditions, formulation standards, and clinical evidence. Search terms were constructed using Boolean operators across the following domains: consumer behaviour and KAP methodology (KAP + beverage + India; knowledge attitude practice + hydration + youth; consumer literacy + functional drink); hydration physiology (sweat sodium + exercise; electrolyte replacement + India climate; isotonic beverage + gastric emptying; hyponatremia + sports); commercial beverage analysis (energy drink + adverse effects + youth; sports drink + sugar content + osmolality; Prime Hydration + formulation; electrolyte beverage + potassium + sodium ratio); herbal pharmacology (Ashwagandha + cortisol + randomised controlled trial; Moringa + amino acid + BCAA; Tulsi + immunomodulation; coconut water + rehydration; curcumin + exercise + anti-inflammatory); and regulatory and market context (FSSAI + functional food + regulation; Ministry of AYUSH + quality mark; India functional beverage market + herbal + synthetic; RTD beverage + India + college).

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Grey literature sources were incorporated using a structured approach. These included annual reports from the Ministry of AYUSH (Government of India); regulatory circulars, notifications, and labelling guidelines from the Food Safety and Standards Authority of India (FSSAI); market intelligence databases including IMARC Group, Grand

View Research, Ken Research, and Bonafide Research; and institutional reports from the World Health Organization, the American College of Sports Medicine, and the European Food Safety Authority where directly applicable to the review's arguments.

Table 1: PRISMA-Aligned Literature Search Summary

Database / Source	Search Terms (examples)	Records Retrieved	Included After Screening
PubMed / MEDLINE	hydration + electrolyte + exercise; KAP + beverage + India; energy drink + youth	2,847	61
Scopus	Ayurvedic adaptogen + clinical trial; herbal functional beverage + review; sweat sodium + physiology	1,904	44
Google Scholar	India college student beverage; FSSAI functional food regulation; coconut water rehydration	1,213	28
Grey Literature	Ministry of AYUSH annual reports; FSSAI circulars; market intelligence databases (IMARC, Grand View)	214	17
TOTAL		6,178	150

Source: Compiled by authors from database screening records. Abbreviations: RTD = Ready-to-Drink.

2.2 Inclusion and Exclusion Criteria

Studies were included if they: (a) were published in peer-reviewed journals indexed in PubMed, Scopus, or Web of Science; (b) addressed beverage consumption behaviour, hydration physiology, functional drink formulation, herbal supplement pharmacology, or related regulatory policy; (c) enrolled participants aged 15–35 years or included data directly applicable to the Indian college student demographic; (d) were published in English; and (e) were accessible in full text. Systematic reviews, meta-analyses, randomised controlled trials, cross-sectional surveys, and authoritative narrative reviews were all eligible for inclusion.

Studies were excluded if they: (a) addressed alcohol or alcoholic beverage consumption exclusively without reference to hydration or functional aspects; (b) were conference abstracts without full-text access; (c) addressed paediatric populations below the age of 15 without relevance to adolescent and young adult physiology; (d) involved animal models without human translational applicability; or (e) were published in grey literature without institutional attribution or verifiable methodology. Commercial beverage formulations were analysed using

publicly available nutritional label data and peer-reviewed comparative formulation analyses, not proprietary or unpublished industry data.

2.3 Data Extraction and Quality Assessment

Data from included primary studies were extracted using a standardised template capturing: study design, population characteristics, geographic setting, beverage type under examination, key outcomes relevant to KAP or physiology, and reported findings. For systematic reviews and meta-analyses, pooled effect estimates and confidence intervals were recorded where available. Methodological quality of primary KAP studies was assessed using Bloom's validated cut-off criteria for knowledge scoring ($\geq 80\%$ = good; 60–79% = average; $< 60\%$ = poor), which has been applied in multiple comparable studies in the Indian context.^{8,9} The quality of randomised controlled trials on herbal interventions was evaluated using the Cochrane Risk of Bias 2 (RoB 2) criteria as reported in included meta-analyses.^{10,11} The six original research gaps were derived through a structured comparative analysis process: commercial beverage nutritional profiles were mapped against established physiological benchmarks from ACSM guidelines, WHO oral rehydration standards, and peer-

reviewed sports nutrition consensus statements; deviations from benchmark were categorised by domain (electrolyte, carbohydrate, economic, regulatory, formulation, literacy); and each gap was validated against at least three independent sources before inclusion in the gap taxonomy.

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and Functional Literacy

The consistent pattern across KAP studies conducted in Indian collegiate settings is one of inflated awareness and deficient literacy. Students reliably demonstrate familiarity with the concepts of hydration, energy, and wellness; they can name branded products in each category and associate certain herbal ingredients with vague health benefits. What they cannot do with any reliability is interpret a nutritional label with critical discernment, identify the physiological mechanism by which an electrolyte beverage should work, distinguish a therapeutically effective dose of an Ayurvedic extract from a sub-threshold decorative inclusion, or recognise the warning signs of hypertonic osmolality, excessive caffeine accumulation, or herb-drug interaction. In a rigorously conducted cross-sectional study among 401 undergraduate medical students in South Kerala a population with considerably greater exposure to health science education than the average college cohort only 35.2% demonstrated good knowledge regarding the health consequences of carbonated beverage consumption, despite 63.1% expressing positive attitudes toward reduction.⁸ This knowledge-attitude split, wherein positive health intentions are not matched by the pharmacological understanding necessary to enact them, recurs across studies from Maharashtra, Telangana, Delhi, and Karnataka with remarkable consistency.^{9,12,13}

The sodium-potassium electrolyte ratio represents one of the most technically significant and consistently underappreciated knowledge gaps. Survey instruments administered in several institutional studies confirm that fewer than 20% of college students could correctly identify sodium as the primary ionic constituent of sweat, or explain why adequate sodium replacement is a precondition of effective rehydration.^{8,14} This gap has direct commercial consequences: students who do not understand sweat physiology cannot evaluate whether a beverage that delivers 700 mg of potassium and 10 mg of sodium is physiologically appropriate for hot-weather exercise and they therefore rely instead on packaging aesthetics, celebrity associations, and price points as surrogate quality signals.¹⁵ Label literacy represents an equally concerning deficit. Studies from multiple Indian institutions confirm that the majority of college students cannot correctly interpret terms such as 'isotonic,' 'osmolality,' or 'daily value percentage' as presented on standard nutritional labels. The 2020 FSSAI labelling regulations mandate that caffeinated beverages display prominent front-of-pack warnings, yet research among medical undergraduates in Telangana found that most students were unaware of this requirement and could

not identify the caffeine content of the beverages they consumed daily.^{16,17} If future healthcare providers demonstrate this level of label blindness, the literacy deficit in the broader undergraduate population is likely considerably more severe.

The attitudinal landscape among Indian college students is characterised by a productive but insufficiently activated cultural asset genuine respect for Ayurvedic tradition and a commercially engineered aspiration toward globally branded products that frequently overrides it in practice. Understanding this dynamic is central to designing interventions that achieve behavioural change rather than merely attitudinal endorsement.

Trust in Ayurvedic botanical preparations is deeply ingrained in Indian family culture and transmitted through lived experience rather than through formal education. Ingredients such as Ashwagandha, Tulsi, Amla, and turmeric are encountered in household kitchens, festival preparations, and intergenerational health rituals long before they appear on supplement labels.^{18,19} This experiential trust is an extraordinary public health asset but it is an asset that the current commercial herbal beverage market exploits through name recognition rather than harvests through genuine clinical delivery. A student who trusts Ashwagandha as a concept, having consumed it in childhood kadha preparations, does not automatically trust a branded RTD product that lists Ashwagandha as its sixth ingredient at an undisclosed concentration but neither does that student possess the pharmacological framework to evaluate the difference.²⁰

Commercial aspiration, mediated through social media and peer influence, constitutes the dominant attitudinal force at the point of purchase. In 2024, approximately 58% of urban Indian consumers reported preference for products labelled as 'sugar-free' or 'natural,' yet this preference did not translate into meaningful scrutiny of actual label content.²¹ The aesthetic grammar of beverage marketing aspirational athleticism, minimalist packaging, celebrity endorsement has been mastered by commercial brands to a degree that Ayurvedic producers have not yet matched, creating a systematic attitudinal pull toward products that invoke health narratives without delivering health outcomes.²²

The urban-rural attitudinal gradient represents a structurally important axis for intervention design. Rural students, maintaining closer contact with traditional herb use and less exposure to digital advertising, exhibit stronger alignment between their stated preferences for natural products and their actual consumption of home-prepared botanical drinks. Urban students demonstrate the sharpest attitudinal dissonance: professing wellness values while purchasing products that contradict them.²³ This gradient suggests that intervention strategies should be calibrated to the digital and social media environments that urban students inhabit, not merely to the informational content of health messaging.

3.3 Practices Domain: The Structural Determinants of Daily Consumption

Consumption practices among Indian college students are, to a far greater degree than is commonly acknowledged in public health literature, determined by structural factors that educational interventions alone cannot resolve. Three

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campus food environment design.

Convenience is the single most consistent predictor of beverage choice in young adult consumer research across multiple global settings, and India is no exception.²⁴ The beverage that can be acquired, opened, and consumed within the fifteen seconds available between a lecture and the next staircase is the beverage that will be consumed regardless of its nutritional composition. Commercially distributed energy drinks and carbonated beverages enjoy profound structural convenience advantages: they are stocked in virtually every campus canteen, every campus-adjacent kirana store, and every vending machine; they require no preparation, no sourcing knowledge, and no storage. Traditional botanical preparations even when the student knows and values them require time, materials, and a kitchen. This is not an attitudinal gap; it is an architectural one.²⁵

Economic stratification shapes practice with equal force. The Indian functional beverage market presents a striking pricing paradox: the most physiologically sound rehydration option available coconut water supplemented with a small quantity of pink rock salt costs between INR 20 and 40 per serving, yet it occupies virtually no shelf space in premium campus retail environments. Imported electrolyte beverages priced at INR 300–450 per serving, which this review demonstrates to be biochemically inferior for sweat

replacement, dominate the aspirational beverage space. The intermediate tier affordable, clean-label, herbal-synthetic hybrid beverages priced between INR 50 and 100 does not yet exist at scale in the Indian market. Students with limited disposable incomes therefore face a choice between premium priced inferior imports and low priced high sugar

Campus food environments are the third structural determinant, and arguably the most actionable. Institutional procurement decisions which beverages appear in college canteens, which brands receive display space in campus stores, which products are available at subsidised prices in student unions collectively constitute the choice architecture within which thousands of beverage decisions are made daily. These decisions are currently made on commercial rather than nutritional grounds, with large beverage corporations wielding distribution advantages that smaller herbal producers cannot match. Institutional procurement policies that mandate the availability of sodium-adequate, low-sugar hydration options at competitive price points would alter the structural landscape of student beverage choice more efficiently than years of educational campaigning.²⁸

4. Comparative Formulation Analysis of Commercial Beverages

Table 2 presents a comparative nutritional and economic profile of six commercial beverage brands available in the Indian market, alongside native coconut water as a comparative benchmark. The data, drawn from product nutritional labels and published comparative analyses, are analysed against ACSM-endorsed physiological standards for hydration beverage composition.

Table 2: Comparative Nutritional, Osmolality, and Economic Profiles of Commercial Beverages Available in the Indian Market

Brand	Purpose	Na ⁺ mg	K ⁺ mg	Sugar g/100ml	Caffeine mg	Osmolality	Price INR
Gatorade	Sport Hydration	270	75	4.4	0	~280 mOsm	₹40–60
Prime Hydration	Electrolyte	10	700	0	0	~200 mOsm	₹300–450
Red Bull 250ml	Energy/Alertness	105	Trace	10.8	80	~610 mOsm	₹110–140
Monster 500ml	High-Stim Energy	370	Trace	10.8	140–160	~590 mOsm	₹110–150
Sting 250ml	Energy	~90	Trace	12.0	~120	~620 mOsm	₹20–30
Enerzal 200ml	Oral Hydration	~460	~780	7.5	0	~330 mOsm	₹25–35
Coconut Water*	Natural Hydration	~105	~250	~3.7	0	~290 mOsm	₹20–40

*Coconut water values represent average composition; Na⁺ increases to ~350–400 mg per 350 ml when supplemented with 0.5 g pink rock salt. Osmolality data derived from published formulation analyses and peer-reviewed comparative studies.^{28,29,30} INR pricing reflects average metro retail 2024–2025.

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4.1 The Sodium Primacy Problem in Sweat Physiology

The physiological logic of hydration beverage design begins with a single biochemical fact: sweat is primarily a sodium solution. During exercise in warm ambient conditions, eccrine sweat glands secrete a fluid whose primary ionic constituent is sodium chloride, with sweat sodium concentrations ranging from approximately 920 to 2300 mg per litre in unacclimatised individuals a range reflecting significant interindividual variation determined by fitness level, acclimatisation status, dietary sodium intake, and environmental temperature.^{31,32} Potassium, by contrast, is lost in comparatively small quantities typically 120 to 160 mg per litre of sweat reflecting the fact that potassium is predominantly an intracellular cation that does not appear in extracellular secretions at concentrations anywhere near those of sodium.³³

The primacy of sodium in hydration physiology extends beyond simple replacement of what is lost. Sodium drives the glucose-sodium cotransport mechanism at the intestinal brush border the process by which ingested fluid is actively absorbed into the circulation making adequate sodium concentration a prerequisite for rapid fluid uptake regardless of the volume consumed.^{34,35} Sodium also maintains plasma osmolality, the osmotic signal that sustains thirst and thereby promotes continued voluntary drinking. A beverage that delivers insufficient sodium fails simultaneously at gastric absorption, thirst maintenance, plasma volume restoration, and prevention of dilutional hyponatremia in individuals who consume large fluid volumes.^{36,37}

Against this physiological standard, the electrolyte profiles of several market-dominant beverages represent a significant formulation failure. Prime Hydration retailing at INR 300–450 per serving and positioned as a premium electrolyte beverage delivers approximately 700 mg of potassium alongside barely 10 mg of sodium per bottle. This electrolyte ratio is inverted relative to every established physiological guideline for sweat replacement: it provides more than four times the recommended K⁺ contribution while delivering less than 5% of the Na⁺ required to maintain plasma osmolality during moderate exercise in Indian summer conditions.^{38,39} Gatorade's profile 270 mg sodium, 75 mg potassium more accurately reflects physiological priorities, though its 21 g of sugar per serving requires contextual evaluation against exercise intensity and duration. Enerzal, an Indian-manufactured oral rehydration beverage, presents a more physiologically appropriate electrolyte balance at a fraction of the imported brands' cost.

4.2 The Sugar Concentration Paradox

The relationship between sugar concentration and hydration efficacy follows a precise non-linear curve that several commercially available beverages violate, in some cases severely. Carbohydrate concentrations of 2–6 g per 100 ml (2–6% weight/volume) facilitate isotonic fluid absorption by driving sodium-glucose cotransport across the intestinal mucosa without exceeding the gastric emptying threshold.⁴⁰

When carbohydrate concentration rises above 8 g per 100 ml (8% w/v), gastric emptying rate slows, intestinal luminal osmolality rises, and the net absorption of water is paradoxically reduced in hypertonic solutions, water may actually be drawn from the circulation into the gut lumen to dilute the hypertonic contents, producing a net dehydrating effect at precisely the moment hydration is claimed.^{41,42}

The beverages reviewed in this analysis demonstrate a striking disregard for this well-established physiological threshold. Red Bull (250 ml) contains approximately 27 g of sugar per serving, representing 10.8 g per 100 ml substantially above the upper absorption limit. Monster Energy (500 ml) contributes a comparable sugar density. Sting Energy, marketed aggressively to price-sensitive Indian youth at INR 20–30 per can, delivers approximately 12 g of sugar per 100 ml alongside 120 mg of caffeine. These formulations are not simply unhealthy in a general chronic disease sense; they are acutely anti-hydrating in the context of exercise and thermal stress which is precisely when they are most commonly consumed.^{43,44}

The physiology of caffeine compounds this problem further. At doses of 80–160 mg which fall within the range delivered by a single Red Bull or Monster serving caffeine exerts a mild diuretic effect through inhibition of renal tubular sodium reabsorption and transient elevation of glomerular filtration rate.⁴⁵ While the acute diuretic effect of caffeine at these doses is modest relative to the fluid volume provided by the beverage, the combination of hypertonic sugar concentration and caffeine-mediated diuresis creates a physiological environment that is net dehydrating under conditions of vigorous exercise and high ambient temperature a double paradox that affects precisely the consumers in whose hands these beverages are most frequently found.⁴⁶

4.3 Osmolality as the Overlooked Clinical Determinant

Osmolality is the total concentration of solutes in a solution, measured in milliosmoles per kilogram (mOsm/kg) — is the most fundamental determinant of whether a beverage accelerates or impedes intestinal fluid absorption, yet it is entirely absent from the labelling of every beverage reviewed in this analysis. Isotonic beverages, with osmolality between 270 and 330 mOsm/kg (approximating plasma osmolality), are absorbed at rates comparable to water and are suitable for hydration during moderate exercise. Hypotonic beverages (200–270 mOsm/kg) are absorbed slightly more rapidly and are appropriate for situations where fluid delivery is the primary priority. Hypertonic beverages (>330 mOsm/kg) require the intestinal mucosa to first dilute the luminal contents with water drawn from the circulation before absorption can proceed an energetically costly process that delays fluid delivery and, under conditions of significant sweating, can produce a net fluid deficit.^{47,48}

Based on published formulation data and osmolality measurements, Red Bull and Monster Energy both present

osmolality values exceeding 500 mOsm/kg, approximately, claim and physiological reality is disclosed to the consumer

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student consuming a can of Monster Energy in the middle of a cricket match on a Mumbai afternoon is not hydrating; they are loading a hypertonic solution whose absorption will be delayed, whose caffeine will promote mild diuresis, and whose sugar will induce an insulin response followed by reactive hypoglycaemia. The product's marketing positions it as an energy enhancement for exactly these athletic scenarios.⁴⁹ The regulatory environment currently provides no mechanism by which this mismatch between marketing

Systematic Formulation Analysis

The following six research gaps represent the primary original scholarly contribution of this review. They were derived through a structured comparative analysis of commercial beverage profiles against established physiological benchmarks, consumer market data, regulatory frameworks, and the KAP literature. Each gap is presented with its evidentiary basis, its clinical and public health implications, and the directions it opens for further investigation.

Table 3: Six Original Research Gaps Identified Through Comparative Formulation and KAP Analysis

Gap Domain	Identified Deficiency	Evidence and Clinical Implication
Gap 1: Electrolyte Inversion	Leading brands prioritise potassium (K ⁺ 700 mg) while neglecting sodium (Na ⁺ ≤10 mg). Sweat is predominantly a sodium solution (920–2300 mg Na ⁺ /L). Products are formulated contrary to sweat physiology.	Rehydration is osmotically driven by Na ⁺ . Low-Na ⁺ beverages cannot restore plasma volume or stimulate thirst. Risk of exercise-induced hyponatremia in Indian summer heat.
Gap 2: Sugar Paradox	Several reviewed beverages contain 10–12 g sugar per 100 ml. Clinical guidelines recommend ≤4 g/100 ml for isotonic absorption. High osmolality (>600 mOsm) slows gastric emptying, counteracting hydration.	Hypertonic beverages draw water into the gut lumen osmotically, worsening net dehydration. Paradoxically anti-hydrating at the very moment hydration is claimed.
Gap 3: Pricing Inequity	Imported electrolyte brands (INR 300–450/serve) deliver inferior Na ⁺ profiles versus native options (coconut water INR 20–40). Premium pricing is anchored to branding, not nutritional merit.	Economic exclusion pushes budget-constrained students toward cheaper, high-sugar alternatives. The most affordable hydration option (coconut water + salt) remains commercially invisible on campuses.
Gap 4: Synthetic-Only Formulation	India lacks a commercially scaled beverage that integrates clinically dosed Ayurvedic adaptogens (Ashwagandha, Moringa, Tulsi) with physiologically balanced electrolytes in a single RTD format.	Hybrid herbal-electrolyte beverage remains an untapped market category. India's botanical heritage is commercially exploited through names on labels rather than therapeutic concentrations in formulations.
Gap 5: Regulatory Blind Spot	No mandatory front-of-pack electrolyte ratio disclosure exists for hydration drinks. FSSAI labelling mandates nutritional facts but does not require isotonicity classification or sweat-replacement adequacy.	Students cannot evaluate electrolyte formulations without specialised knowledge. Regulatory silence enables mislabelling of hypertonic, low-sodium products as 'superior hydration.'
Gap 6: KAP-Literacy Disconnect	Students demonstrate brand familiarity with herbal ingredients (Ashwagandha, Tulsi) but cannot identify therapeutically effective doses, extraction standards, or herb-drug interactions.	Surface-level awareness without pharmacological understanding enables predatory marketing. The 'natural equals safe' fallacy thrives in a knowledge vacuum and cannot be corrected without structured education.

Abbreviations: RTD = Ready-to-Drink; Na⁺ = sodium; K⁺ = potassium; FSSAI = Food Safety and Standards Authority of India; KAP = Knowledge, Attitudes, Practices.

Gap 1: The Electrolyte Inversion — A Market-Wide Formulation Failure

The most clinically significant gap identified through this review is the systematic inversion of the sodium-to-potassium ratio across market-dominant hydration beverage formulations. During exercise in India's tropical climate where ambient temperatures routinely exceed 35°C and relative humidity exceeds 70% during monsoon season sweat rates of 1.0–2.5 litres per hour are common among physically active young adults, and sweat sodium losses of 1500–3000 mg per hour represent the primary electrolyte challenge.^{31,33} No evidence base supports potassium as the priority replacement electrolyte under these conditions: yet

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per serving.

This gap is not merely a commercial oversight it represents a fundamental misunderstanding, or deliberate misrepresentation, of sweat physiology that has been allowed to proliferate through the Indian market in the absence of mandatory formulation standards for beverages making hydration claims. The research gap it opens is twofold: first, no clinical trial has yet examined the acute hydration outcomes of the specific potassium-dominant electrolyte profiles marketed in India among exercising young adults in realistic Indian climatic conditions; second, no regulatory mechanism currently exists to prevent the commercial expansion of physiologically contradictory formulations.^{50,51}

Gap 2: The Sugar Paradox — When Hydration Beverages Dehydrate

The identification that several leading beverages contain carbohydrate concentrations (10–12 g/100 ml) that exceed the absorption threshold for isotonic gut transport (≤ 8 g/100 ml) and approach or surpass hypertonic osmolality thresholds represents a paradox of significant public health consequence. These are products that are actively marketed for hydration and exercise recovery, consumed by students who believe they are addressing dehydration, but which under the physiological conditions of their most frequent use slow gastric emptying, raise intestinal osmolality, draw fluid into the gut lumen, and may produce net fluid deficits in individuals who are simultaneously sweating at high rates.^{40,41}

The research gap here is substantial and insufficiently acknowledged in the Indian literature. No Indian study has measured the acute hydration status of college students before and after consumption of the specific commercial beverages that dominate the campus market under representative exercise and thermal conditions. The existing evidence base draws primarily from temperate-climate studies using Western brands and populations that are not directly transferable to the Indian context of high ambient

temperature, high sweat rates, and habitual multi-serving consumption patterns.^{52,53}

Gap 3: The Pricing Inequity — Premium Price for Inferior Physiology

The economic analysis embedded in this review reveals a market inversion of troubling dimensions: the beverage that delivers the most physiologically appropriate electrolyte profile for Indian exercise conditions — coconut water supplemented with pink rock salt — is available for INR 20–40 per serving, while the premium import that delivers an electrolyte profile physiologically contraindicated for sweat replacement retails at INR 300–450 per serving. This represents a price differential of 8–15 times for a product

The pricing gap reflects and reinforces a market failure in which premium pricing functions as a quality signal in the absence of mandatory performance disclosure. Students who cannot evaluate electrolyte profiles rely on price as a heuristic for efficacy — a heuristic that consistently directs them toward more expensive, less physiologically appropriate options. The research gap lies in the absence of economic health outcome modelling: no study has estimated the aggregate hydration-related health cost attributable to the pricing-driven misallocation of student beverage spending in India toward premium, physiologically inferior imports and away from affordable, scientifically superior indigenous options.⁵⁵

Gap 4: The Missing Hybrid — India's Untapped Formulation Frontier

Perhaps the most commercially and scientifically significant gap identified through this review is the complete absence from the Indian market of a commercially scaled, affordably priced beverage that integrates clinically dosed Ayurvedic adaptogens with a physiologically balanced synthetic electrolyte base. The Indian nutraceutical sector has produced excellent single-dimension products: Ayurvedic herbal drinks that carry traditional credibility but lack electrolyte science; and synthetic electrolyte beverages that address sweat replacement but contain none of the adaptogenic, anti-inflammatory, or immunomodulatory properties that the Indian botanical heritage uniquely offers. The hybrid format — simultaneously a sports hydration beverage and an adaptogenic wellness product, priced accessibly for campus consumers — does not yet exist at scale.^{56,57}

This formulation gap is not a technical impossibility. The clinical evidence for combining physiologically balanced electrolytes (sodium 200–400 mg, potassium 75–100 mg per serving) with standardised Ashwagandha extract (300 mg), Moringa powder (5 g), and natural glucose (3–4 g/100 ml for transport facilitation) in a single RTD format presents no identified incompatibility. The barrier is commercial rather

than scientific: no Indian brand has yet invested in the product development, clinical validation, regulatory approval, and distribution infrastructure required to bring such a formulation to scale. This represents the single largest untapped opportunity in the Indian functional beverage sector, and the single largest contribution this review's gap analysis can make to innovation-directed research.^{58,59}

Gap 5: The Regulatory Visibility Gap — No Osmolality Disclosure, No Isotonicity Standard

The current FSSAI regulatory framework for functional beverages and nutraceuticals, anchored in the Health Supplements and Nutraceuticals Regulations of 2016 and the Labelling and Display Regulations of 2020, mandates disclosure of energy, protein, carbohydrate, fat, and sodium content per 100 ml or per serving.⁶⁰ It does not require disclosure of osmolality, isotonicity classification, or electrolyte ratio — the three parameters that most directly determine a beverage's physiological suitability for hydration purposes. This regulatory silence creates a space

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mechanism for consumer verification.

The research gap this opens is both regulatory and clinical: a systematic analysis of which currently marketed Indian beverages would fail an osmolality-based isotonicity standard if one were introduced, and a modelling exercise estimating the consumer behaviour change that mandatory osmolality disclosure would produce, would constitute a significant contribution to regulatory science in India. International comparators exist — the European Food Safety Authority and the UK's NHS Choices both provide osmolality guidance for sports beverages — but no equivalent Indian framework has been developed or proposed.^{61,62}

Gap 6: The KAP-Literacy Disconnect — Familiarity Without Pharmacological Understanding

The sixth and epistemologically deepest gap identified through this review is the systematic mismatch between students' recognition of herbal ingredient names and their

absence of pharmacological understanding of those same ingredients. Students who grew up consuming Ashwagandha in household preparations know that it is associated with stress relief; they do not know that the clinically effective dose in controlled trials ranges from 250 to 600 mg of standardised extract per day, that a beverage listing 'Ashwagandha extract' without disclosing the concentration may contain sub-milligram amounts, that its cortisol-modulating effects require 4–12 weeks of consistent supplementation to manifest, or that high-dose concentrated preparations have been associated with reversible hepatic enzyme elevation in susceptible individuals.^{10,11,18}

This knowledge deficit is not benign. It generates false confidence in underdosed commercial products, prevents students from distinguishing evidence-based formulations from marketing-driven imposters, and leaves them unprepared to recognise or report adverse effects from concentrated botanical extracts. The research gap it identifies is a curriculum gap as much as a market gap: no

dose standards, regulatory labelling requirements, and the evidence hierarchy for functional food claims — as a component of undergraduate education in health sciences, nutrition, or pharmacy. This absence represents a structural failure of preventive health education whose consequences compound with every new brand that enters an already oversaturated and under-regulated marketplace.^{63,64}

6. Pharmacological Evidence for Ayurvedic Herbal Alternatives

The case for incorporating Ayurvedic botanical ingredients into functional hydration beverages rests on a growing body of clinical evidence that extends well beyond the anecdotal and ethnopharmacological foundations that have historically characterised this field. Table 4 summarises the principal botanicals, their bioactive constituents, and the clinical outcomes supported by randomised controlled trial evidence.

Table 4: Pharmacological Evidence Base for Principal Ayurvedic Ingredients Proposed for Hybrid Functional Beverage Integration

Botanical	Bioactive Constituents	Clinically Validated Effects	Proposed Beverage Integration
Withania somnifera (Ashwagandha)	Withanolides, alkaloids, saponins	Cortisol ↓ (-1.16 µg/dL); aerobic VO ₂ max ↑; perceived stress ↓; endurance ↑	300 mg standardised root extract in isotonic electrolyte base; RTD format
Moringa oleifera	BCAAs, quercetin, chlorogenic acid, chelated Mg ²⁺ /K ⁺	Muscle recovery ↑; anti-inflammatory; natural mineral chelation improves intestinal absorption	5–10 g leaf powder in coconut water + rock salt electrolyte blend

Ocimum sanctum (Tulsi)	Eugenol, rosmarinic acid, ursolic acid, flavonoids	Immunomodulation; antioxidant enzyme induction (SOD, CAT); cortisol attenuation	Aqueous extract in post-exercise recovery beverage; paired with black pepper for bioavailability
Curcuma longa (Turmeric)	Curcuminoids (curcumin, bisdemethoxycurcumin)	NF-κB suppression; IL-6 ↓; post-exercise DOMS reduction; antioxidant	100 mg curcumin + piperine (5 mg) in warm electrolyte drink; honey as natural sweetener
Camellia sinensis (Green Tea)	EGCG, L-Theanine, low-dose caffeine	Cognitive clarity ↑; caffeine-L-theanine synergy reduces anxiety; EGCG antioxidant	Cold-brew extract; ≤200 mg caffeine equivalent; must carry hepatotoxicity warning at concentrated doses
Zingiber officinale (Ginger)	Gingerols, shogaols, paradols	Anti-nausea; anti-inflammatory (COX-2 inhibition); gastric emptying facilitation	Ginger-lemon electrolyte base; promotes GI comfort during rehydration

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11, 2025.

6.1 *Withania somnifera* (Ashwagandha): The Evidence Frontier

The evidence base for Ashwagandha's adaptogenic effects has matured substantially over the past decade, transitioning from reliance on traditional pharmacognosy and small-scale observational data to a corpus of randomised controlled trials that support its clinical utility with moderate-to-high confidence across several outcome domains. The herb's withanolide constituents — particularly withaferin A and withanolide D exert their primary adaptogenic effects through modulation of the hypothalamic-pituitary-adrenal axis: suppression of corticotropin-releasing hormone secretion at the hypothalamic level reduces downstream adrenocorticotrophic hormone output and thereby attenuates cortisol production at the adrenal cortex.^{65,66}

A systematic review and meta-analysis published in 2025, synthesising seven randomised controlled trials involving 488 participants and applying PRISMA guidelines with Cochrane RoB 2 quality assessment, reported a statistically significant reduction in serum cortisol following Ashwagandha supplementation (mean difference -1.16 µg/dL; 95% CI: -1.64 to -0.69; P < 0.001).¹⁰ Effective doses in included trials ranged from 250 to 600 mg of standardised root extract daily, administered for periods of four to twelve weeks. A parallel systematic review of biopsychological effects in athletes, published in 2025, confirmed improvements in VO₂ max, muscular endurance, countermovement jump performance, and subjective recovery quality in both athletic and non-athletic populations at 300–600 mg daily.¹¹

For the Indian college student enduring examination season — a period characterised by sustained cortisol elevation, disrupted sleep architecture, heightened perceived stress, and compromised immune function — these pharmacological properties address a genuine and common

physiological need. The distinction between Ashwagandha's adaptogenic mechanism and caffeine's adenosine blockade mechanism is clinically important: where caffeine produces an acute alertness spike followed by rebound fatigue and potential dependency, Ashwagandha progressively attenuates the hormonal substrate of stress without generating tolerance, withdrawal, or the neurotoxicity associated with high-dose caffeine.^{67,68}

The safety profile of standardised Ashwagandha extract at clinically studied doses (250–600 mg/day) is generally favourable, with adverse effects in clinical trials limited to mild gastrointestinal symptoms in a small minority of participants.⁶⁹ The critical caveat warranting explicit mention in any product that incorporates Ashwagandha — is the emerging case-series literature documenting reversible hepatotoxic reactions at doses substantially exceeding studied ranges (>1000 mg/day) or in individuals with underlying hepatic vulnerability.⁷⁰ This underscores the necessity of dose transparency on beverage labels and the inadequacy of the current regulatory environment, which permits products to list Ashwagandha without disclosing the concentration delivered per serving.

6.2 *Moringa oleifera*: Nutritional Completeness for the Exercising Student

Moringa oleifera leaf powder represents one of the most nutritionally dense botanical ingredients available from Indian plant sources, and its relevance to the functional hydration beverage context is multidimensional. Its protein fraction — comprising approximately 25–30% of dry leaf weight — contains all nine essential amino acids including leucine, isoleucine, and valine, the three branched-chain amino acids that are rate-limiting for muscle protein synthesis and post-exercise recovery.^{71,72} For college students who cannot afford commercial BCAA supplements but engage in regular athletic activity, *Moringa* powder in a

beverage base represents a genuinely accessible recovery nutrition strategy.

Moringa's mineral content is equally noteworthy. Potassium, magnesium, and calcium are present in substantial quantities, and the organic acid ligands (chlorogenic acid, quercetin glucosides) in which these minerals occur in plant tissue may enhance intestinal absorption relative to the isolated inorganic mineral salts used in synthetic sports beverages — a hypothesis that is mechanistically plausible based on known chelation chemistry and warrants controlled investigation in the sports nutrition context.^{73,74} The anti-inflammatory potential of Moringa's quercetin and isothiocyanate content provides an additional dimension of post-exercise utility, potentially attenuating the cytokine-driven inflammatory cascade that produces delayed onset muscle soreness following high-intensity exercise.⁷⁵

6.3 Ocimum sanctum (Tulsi): Immunomodulation and Post-Exercise Resilience

Tulsi's clinical relevance to the active college student lies primarily in its immunomodulatory and antioxidant properties, which address the transient immune suppression — commonly described as the 'open window' — that follows bouts of high-intensity physical exercise. During and immediately after intense activity, reactive oxygen species generated by mitochondrial electron transport chain dysregulation and by activated immune effector cells create an oxidative environment that impairs leukocyte function and elevates susceptibility to upper respiratory tract infections.^{76,77}

The eugenol and rosmarinic acid constituents of Tulsi induce the expression of antioxidant enzymes — superoxide dismutase, catalase, and glutathione peroxidase — that directly counter this reactive oxygen species burden.⁷⁸ Tulsi's ursolic acid fraction has been shown to modulate NF- κ B signalling, reducing proinflammatory cytokine production (IL-1 β , IL-6, TNF- α) that contributes to exercise-induced muscle damage.⁷⁹ Its inclusion in a post-exercise recovery beverage, combined with black pepper (5 mg piperine per serving to enhance bioavailability of polyphenols through glucuronidation inhibition) represents

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currently marketed on commercial beverage labels.⁸⁰

6.4 Coconut Water as the Indigenous Electrolyte Vehicle

Coconut water's natural electrolyte composition approximately 105 mg sodium, 250 mg potassium, and 3.7 g natural sugars per 100 ml in its unsupplemented form situates it as a near-isotonic base that requires minimal modification to meet ACSM standards for exercise hydration.^{81,82} The addition of a small quantity of pink rock salt (approximately 0.5 g per 350 ml serving) elevates the sodium content to approximately 350–400 mg within the range recommended for sweat replacement during moderate to vigorous exercise in warm conditions.

Critically, coconut water's natural glucose content (predominantly as fructose and glucose in near-equal proportions) provides the substrate required for sodium-glucose cotransporter activation in the intestinal mucosa, driving rapid fluid uptake without the osmotic penalty of the concentrated sugar solutions found in commercial energy drinks.^{83,84} The beverage is isotonic, naturally coloured, naturally flavoured, contains no synthetic preservatives or artificial sweeteners, and is produced domestically in India at a cost that places it within reach of virtually every college student. That it remains commercially marginalised relative to imported electrolyte brands is entirely an artefact of distribution investment and marketing, not of physiological merit.⁸⁵

7. The Regulatory Landscape: FSSAI, AYUSH, and the Clean-Label Imperative

7.1 Current FSSAI Framework

India's regulatory architecture for functional beverages is anchored in a set of FSSAI instruments that collectively address ingredient safety, nutritional labelling, health claim substantiation, and advertising standards: the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Functional Foods and Novel Food) Regulations of 2016; the Food Safety and Standards (Labelling and Display) Regulations of 2020; and the Food Safety and Standards (Advertising and Claims) Regulations of 2018.^{60,86} Together, these instruments mandate that manufacturers declare active ingredient identities and quantities, prohibit health claims that are not substantiated by scientific evidence, require front-of-pack warning labelling for products exceeding defined caffeine thresholds, and provide for regulatory action including product recall and financial penalties for non-compliance.

In practice, however, enforcement capacity has not matched regulatory ambition. Over 5,000 product certifications were granted by FSSAI in 2023, yet approximately 15% of new nutraceutical and functional food products launched that year subsequently faced compliance queries related to undisclosed ingredients, inadequately substantiated health claims, or labelling omissions.⁸⁷ One well-documented enforcement action involving an energy drink whose

resulted in their withdrawal within 45 days of launch, but the product had by that point reached a significant number of student consumers in campus retail channels.⁸⁸

7.2 FSSAI's 2023 Sugar Labelling Regulations and Their Implications

In 2023, FSSAI introduced strengthened guidelines requiring manufacturers to prominently display sugar content on packaging and to disclose when a product contains added sugars above threshold levels.⁸⁹ These guidelines are a meaningful step toward nutritional transparency, but they address sugar quantity rather than the osmolality or absorption implications of sugar concentration the parameters that are most directly relevant to the anti-

hydrating effects identified in Gap 2 of this review. A student who can read that a beverage contains 27 g of sugar per serving is not equipped, without further context, to understand that this concentration creates a hypertonic solution that will slow gastric emptying and impair net fluid absorption during exercise.

7.3 The AYUSH Quality Mark and Its Underutilised Potential

The Ministry of AYUSH's quality certification frameworks including the AYUSH Quality Mark for Ayurvedic products represent an institutional mechanism for distinguishing evidence-aligned herbal formulations from products that merely invoke traditional nomenclature.⁹⁰ A visibly displayed AYUSH Quality Mark communicates, at minimum, that the botanical ingredients have been tested for identity, purity, and freedom from adulterants and heavy metal contamination criteria that address the most immediate quality-related anxieties of the safety-conscious consumer. The certification's penetration among college students, however, remains negligible; few students in available surveys could identify what the AYUSH mark signifies or locate it on product packaging they regularly use.^{20,91}

The regulatory research gap this identifies is a communication gap as much as a policy gap: AYUSH certification exists but has not been designed, positioned, or promoted as a consumer-facing quality signal in the competitive beverage marketplace. The development of a simplified, visually distinctive 'AYUSH Verified' seal analogous to the USDA Organic or EU Ecolabel in terms of consumer recognition and its systematic promotion through campus health programmes and social media would convert an underutilised regulatory asset into a functioning market signal.

8 Strategic Recommendations: A Multidimensional

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Literacy

The foundational recommendation emerging from this review is a shift in the objective of beverage-related health education from awareness generation which the available evidence suggests is already relatively high among Indian college students to functional literacy development. Functional literacy, in this context, means the capacity to interpret a nutritional label critically, to identify the physiological basis for an electrolyte formulation claim, to distinguish between evidence-based and marketing-driven herbal ingredient deployments, and to make an informed beverage choice under real-world conditions of time pressure, social influence, and economic constraint.^{63,64}

University-based functional beverage literacy modules should cover: (1) basic sweat electrolyte physiology, including the primacy of sodium over potassium and the concept of osmolality; (2) carbohydrate concentration and its effect on gastric emptying and net fluid absorption; (3) caffeine pharmacology, cumulative daily loading, and the

markers of dependence; (4) Ayurvedic herbal dose standards, extraction methodology, and the evidence hierarchy for specific ingredients; (5) FSSAI regulatory requirements and how to verify manufacturer compliance; and (6) economic comparison of indigenous versus imported beverage options. These modules are best delivered through peer-led workshops, campus health centre programming, and social media content produced by student wellness ambassadors rather than through didactic lectures that lack the cultural currency to reach this demographic.

8.2 Product Innovation: The Herbal-Synthetic Hybrid Imperative

The most impactful single commercial recommendation emerging from this gap analysis is the development and scaling of a herbal-synthetic hybrid functional beverage that addresses every dimension of the identified market failure simultaneously. The optimal formulation profile, derived from the physiological and pharmacological evidence synthesised in this review, would include: sodium at 200–350 mg per serving (supporting sweat replacement under Indian climatic conditions); potassium at 75–100 mg per serving (complementary, not primary); carbohydrate at 3–4 g per 100 ml in a mixed glucose-fructose format (facilitating cotransport absorption without exceeding osmolality thresholds); standardised *Withania somnifera* root extract at 300 mg per serving (verified by HPLC for withanolide concentration); *Moringa oleifera* leaf powder at 5 g per serving; and natural flavouring from lemon or ginger (enhancing palatability and providing gingerol anti-inflammatory properties).^{92,93}

This formulation would be: (a) physiologically appropriate for sweat replacement in the Indian climate; (b) within the carbohydrate absorption window; (c) pharmacologically meaningful for stress modulation and recovery; (d) domestically sourceable from Indian agricultural producers;

commercial beverages; and (e) eligible for AYUSH Quality Mark certification upon compliance with quality standards. No such product currently exists in the Indian market. Its development represents the precise opportunity that this review's gap analysis has been constructed to identify.

8.3 Regulatory Reform: Three Priority Actions

Three specific regulatory reforms are proposed as priorities. First, FSSAI should introduce mandatory osmolality disclosure for all beverages marketed as hydration, sports, or electrolyte products, alongside a standardised three-tier classification system (hypotonic, isotonic, hypertonic) displayed prominently on product labelling. This single reform would, by making physiological category visible to consumers at the point of purchase, create market accountability for the hypertonic, anti-hydrating formulations currently marketed under hydration claims.

Second, FSSAI should require that any functional beverage listing a herbal ingredient on its principal display panel disclose the standardised extract concentration per serving

in milligrams, the plant part used (root, leaf, seed), and the extraction method and ratio information that is currently voluntary and rarely provided. This would enable consumers and healthcare providers to evaluate whether listed botanical concentrations are within clinically studied ranges or represent cosmetic label inclusions.

Third, the AYUSH Quality Mark should be repositioned as a consumer-facing trust signal through mandatory display requirements for products making Ayurvedic or herbal health claims, combined with a public awareness campaign delivered through campus health channels, school curricula, and the social media platforms frequented by the 18–25 age cohort. The regulatory infrastructure for this repositioning exists; what is required is political will and cross-ministerial coordination between the Ministry of AYUSH and FSSAI.

8.4 Institutional and Campus-Level Structural Reform

Campus food environments require deliberate nutritional redesign. Institutional procurement policies should mandate that college canteens and campus retail outlets stock at minimum: (a) one sodium-adequate, low-sugar hydration beverage (meeting the osmolality and electrolyte standards outlined above) at a subsidised price; and (b) fresh coconut water as an indigenous hydration option where supply chains permit. Campus vending machines should be subject to beverage health scoring requirements analogous to traffic light labelling systems implemented in healthcare settings in the United Kingdom and Australia. These structural changes require regulatory mandate rather than voluntary industry adoption; the evidence from analogous interventions in school food environments is that structural changes significantly outperform educational campaigns in generating sustained behaviour change.^{94,95}

9. Discussion

The six research gaps presented in this review constitute, collectively, an indictment of the functional beverage market's failure to serve Indian college students with products that reflect either the physiological science of hydration or the pharmacological heritage of Ayurveda. They document a market that has optimised for commercial success — through celebrity endorsement, aspirational packaging, and distribution scale — at the direct expense of the hydration outcomes it claims to deliver. They identify a regulatory environment that has established the correct requirements but lacks the enforcement granularity to prevent the sale of hypertonic, sodium-deficient, over-sugared formulations under hydration branding. And they reveal an educational landscape that has produced health

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evaluate them.

The findings of this review should be interpreted with an appreciation of several limitations. The comparative formulation analysis relies on publicly available nutritional label data, which represent manufacturer declarations rather than independently verified composition measurements; independent laboratory analysis of commercially available

Indian beverage brands is a research priority that this review's gap taxonomy explicitly highlights. The KAP data synthesised in this review derives primarily from studies conducted in medical and health science colleges, which likely present more favourable knowledge profiles than the broader undergraduate population; KAP instruments validated for the general Indian college population across diverse disciplines and institutional types are needed. And the market gap analysis, while grounded in published market intelligence data, reflects conditions as of early 2025 and may not fully capture product launches or regulatory changes occurring in the rapidly evolving Indian functional beverage sector.

The proposal for a herbal-synthetic hybrid beverage deserves explicit acknowledgement as a recommendation that bridges the scientific and entrepreneurial domains. This review is not positioned as a product development brief, and the formulation parameters proposed represent a starting point for rigorous product development, clinical validation, and regulatory engagement rather than a finalised recipe. The intention is to articulate, with sufficient scientific precision, what the evidence base would support and to create a research and innovation agenda that India's nutraceutical industry can adopt as a strategic direction. If India's botanical resources, manufacturing capabilities, regulatory frameworks, and clinical research capacity can be aligned toward this specific formulation opportunity, the result could be not merely a commercially successful product but a genuine public health contribution: an affordable, evidence-based, culturally authentic beverage that replaces premium-priced, physiologically deficient imports in the hands of India's college students.

The broader implication of this work is that the KAP gap in Indian college student beverage consumption is not primarily a knowledge problem, an attitude problem, or a practice problem in isolation it is a systemic problem that requires systemic solutions. Individual students cannot be expected to navigate a market that is poorly regulated, a campus environment that is structurally biased toward nutritionally inferior products, and a social media landscape that amplifies commercial claims while suppressing scientific critique. The responsibility for closing this gap lies with institutions: universities, regulatory bodies, government ministries, and the Indian nutraceutical industry. This review has attempted to give those institutions the evidence base and the analytical framework they need to act.

sources spanning hydration physiology, herbal pharmacology, consumer behaviour research, and Indian regulatory policy to produce a structured critique of the functional beverage landscape as experienced by Indian college students. Through the application of the KAP framework, it has documented consistent and actionable gaps between what students know, believe, and do regarding

beverages gaps that are structurally reinforced by market forces, campus architecture, and regulatory inadequacy. The six original research gaps identified through comparative formulation analysis constitute the primary scientific contribution of this work. They establish, with evidence-anchored precision, that India's dominant commercial hydration beverages systematically invert electrolyte priorities relative to sweat physiology; deploy carbohydrate concentrations that are anti-hydrating under exercise conditions; command premium prices for physiologically inferior profiles; exploit Ayurvedic nomenclature without delivering therapeutic concentrations; operate in a regulatory environment that discloses insufficient information for consumer evaluation; and are consumed by a population whose literacy gaps leave them unable to detect any of the above.

India does not yet possess a finest-in-class hydration beverage one that is simultaneously sodium-adequate, osmolality-appropriate, affordably priced, botanically authentic, clinically dosed, and regulatory-compliant. The opportunity to create that beverage exists. The botanical heritage is available. The clinical evidence is maturing. The regulatory framework, imperfect as it is, can be strengthened. What is required is the collective will of researchers, policymakers, entrepreneurs, and educators to recognise that a population of hundreds of millions of young Indians deserves better than what the current market provides and to build the science, the products, and the institutions that can deliver it.

Author Contributions: Conceptualisation, literature synthesis, gap analysis, and manuscript preparation: primary author. Methodological design and critical review: contributing authors and supervising mentor.

Funding: This review received no specific financial support from any public, commercial, or not-for-profit funding body.

Conflict of Interest: The authors declare no conflicts of interest.

Data Availability: No new primary data were generated. All data supporting the findings of this review are drawn from cited published sources.

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