International Journal of Diabetes in Developing Countries (October–December 2025) 45(4):803–814
https://doi.org/10.1007/s13410-025-01559-x

GUIDELINES

Research Society for the Study of Diabetes in India (RSSDI) multidisciplinary expert consensus recommendations on role of oral fluid, electrolytes, and energy management in persons with diabetes

Sanjay Agarwal[1] · Manoj Chawla[2] · Sanjay Kalra[3] · Sunil Jain[4] · A. G. Unnikrishnan[5] · L. Sreenivasa Murthy[6] · Neeta Deshpande[7] · Banshi Saboo[8] · Mangesh Tiwaskar[9] · Eileen Canday[10] · Vijay Vishwanathan[11] · Rakesh Sahay[12] · Anuj Maheshwari[13]

Received: 5 September 2025 / Accepted: 9 September 2025 / Published online: 16 October 2025
© The Author(s) 2025

Abstract

Fluid, electrolyte, and energy (FEE) management plays a crucial role in the recovery of patients with type 2 diabetes mellitus (T2DM) and prediabetes, especially during acute non-diarrheal illnesses. However, current diabetes management guidelines often lack specific recommendations on how to address the unique FEE needs of these patients, leading to potential gaps in managing dehydration and energy deficits. In this article, we aimed to develop practical consensus recommendations on the role of FEE management in persons with diabetes (PWDs). Modified Delphi consensus methodology was utilized to reach a consensus. A scientific committee comprising 11 experts from India formed the panel. Relevant clinical questions within four major domains were formulated for presentation and discussion: (i) burden of FEE deficits in PWDs; (ii) assessment of FEE deficits in PWDs; (iii) role of FEE management in the recovery of T2DM; and (iv) importance of sustained energy concepts in meeting the energy requirements of T2DM. The consensus level was classified as "Yes" (when ≥ 70% of participants agree/strongly agree or disagree/strongly disagree with a statement) and "No" (when < 70% of participants agree/strongly agree or disagree/strongly disagree with a statement). The questions that lacked agreement were discussed during the virtual meeting. The experts agreed that slow-release carbohydrates, such as isomaltulose, D-tagatose, and trehalose, offer an effective solution for meeting energy requirements while stabilizing blood glucose levels and reducing glycemic variability. Ready-to-drink formulations that combine electrolytes, fluids, and slow-release carbohydrates provide a balanced approach to hydration and energy needs, which is particularly beneficial for patients with T2DM who are experiencing dehydration. Incorporating tailored FEE recommendations into existing guidelines could significantly enhance patient care by ensuring optimal hydration, electrolyte balance, and glucose control. This approach would be especially beneficial for patients with comorbidities or those at a higher risk of dehydration, supporting improved recovery and metabolic stability.

Keywords Dehydration · Diabetes · Fluid, electrolyte, and energy (FEE) · Sustained release · Oral rehydration

✉ Manoj Chawla
linadiabetes@gmail.com

[1] Department of Medicine, Ruby Hall Clinic, Pune, India

[2] Lina Diabetes Care & Mumbai Diabetes Research Centre, Mumbai, Maharahstra, India

[3] Bharti Hospital, Karnal, Haryana, India

[4] TOTALL Diabetes Hormone Institute, Indore, Madhya Pradesh, India

[5] Chellaram Diabetes Institute, Pune, Maharashtra, India

[6] Life Care Hospital & Research Center, Bangalore, Karnataka, India

[7] CentraCare Super Speciality Hospital & Medical Research Centre, Belgaum, Karnataka, India

[8] Dia Care-Diabetes Care & Hormone Clinic, Ahmedabad, Gujarat, India

[9] Shilpa Medical Research Centre, Mumbai, Maharashtra, India

[10] Department of Nutrition and Dietetics, Sir H N Reliance Foundation Hospital and Research Centre, Mumbai, Maharashtra, India

[11] MV Hospital for Diabetes and Prof M Viswanathan Diabetes Research Centre, Royapuram Chennai, India

[12] Osmania Medical College, Osmania General Hospital, Hyderabad, India

[13] Department of General Medicine, Hind Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

Introduction

India has one of the highest diabetes burdens worldwide, with a rising prevalence of both type 1 and type 2 diabetes mellitus (T2DM). The International Diabetes Federation (IDF) reports that, in 2021, the prevalence of diabetes among adults in India was approximately 75 million, positioning India as a leading contributor to the global diabetes population [1]. The ICMR-INDIAB study reports that diabetes prevalence in India varies widely, from 4.8% in Uttar Pradesh to 26.4% in Goa, with higher rates in southern and northern urban areas. Meanwhile, prediabetes is more common in central and northern regions, particularly in less developed states where the diabetes-to-prediabetes ratio is 1:2, contrasting with a 1:1 ratio in more developed regions like Chandigarh and Tamil Nadu [2]. This trend calls for effective management strategies to minimize complications and enhance patient outcomes. A key component of diabetes care is the proper management of fluid, electrolyte, and energy (FEE) requirements, which is especially crucial during acute illnesses or physical stress. Poor FEE management can worsen hyperglycemia, cause metabolic disturbances, and complicate the progression of the disease [3, 4].

Excessive water and electrolyte loss, or dehydration, is prevalent in persons with diabetes (PWDs), as metabolic changes interfere with fluid balance and hinder blood glucose control. An important hormone for preserving plasma osmolality—arginine vasopressin (AVP)—is frequently raised in patients with diabetes, which might worsen fluid imbalance. Insulin resistance and glucose intolerance are caused by the altered function of AVP in gluconeogenesis, glycogenolysis, and glucose uptake in adipose tissue in diabetes. Furthermore, copeptin—a pre-pro-vasopressin peptide—that mimics AVP action has been linked to insulin resistance, metabolic syndrome, and T2DM [5].

Hyperosmolar hyperglycemic state and diabetic ketoacidosis (DKA) are two serious consequences that can result from this hormonal imbalance, which frequently exacerbates hyperglycemia [6–8]. Additionally, inadequate hydration may impact kidney function, elevating the risk of chronic complications and associated electrolyte imbalances, including dysnatremias, hypokalemia, and magnesium depletion, which complicate diabetes management. Electrolyte imbalances, notably sodium fluctuations, are also prevalent among persons with diabetes, often complicating hyperglycemia, kidney dysfunction, and respiratory health issues [9–11] (Table 1).

Given the rising prevalence of diabetes in India, there is a critical need for expert-driven guidelines to standardize the management of oral fluids, electrolytes, and energy requirements (Table 2).

This Delphi consensus aims to provide evidence-based recommendations specifically tailored to the needs of Indian healthcare settings, addressing key challenges in FEE management in diabetes care and offering strategies to reduce dehydration and electrolyte imbalance complications for improved patient outcomes.

Methodology

Panel selection

A panel of 11 experts was selected based on their academic achievements, involvement in clinical research, and diverse experiences in the field of fluid therapy from different parts of India. A chair was designated to lead the consensus process (Fig. 1).

Evidence review

A comprehensive electronic search was conducted on the PubMed/MEDLINE database to identify pertinent articles published from January 2000 to August 2024, using diverse keyword combinations, including "electrolytes," "oral

Table 1 Symptoms and potential complications of dehydration and electrolyte imbalance in diabetes

Aspect	Symptoms	Potential complications
Dehydration in diabetes	- Increased thirst, dry mouth - Dark/concentrated urine - Fatigue, dizziness	- Worsened blood glucose control - Diabetic ketoacidosis (DKA) - Hyperosmolar hyperglycemic state (HHS) [6–8]
Electrolyte imbalance	- Muscle cramps, weakness - Confusion, irregular heartbeats - Nausea, headache	- Hyponatremia or hypernatremia - Hypokalemia (risk of cardiac issues) - Kidney dysfunction [9, 10]

DKA, diabetic ketoacidosis; *HHS*, dyperosmolar hyperglycemic state

Table 2 Management tips for dehydration and electrolyte imbalance in diabetes [5]

Aspect	Management tips
Hydration	- Drink plenty of water or low-sugar, caffeine-free beverages regularly - Avoid alcohol, as it can dehydrate
During heat/exercise	- Exercise in cooler times or air-conditioned spaces; carry water - Watch for heat exhaustion signs, e.g., dizziness, sweating, and cramps, and act quickly to rehydrate if symptoms arise
Glucose monitoring	- Check blood glucose regularly, especially in warm climates, as heat can affect levels
Proactive hydration	- Keep water accessible, as thirst may not accurately reflect hydration needs in diabetes

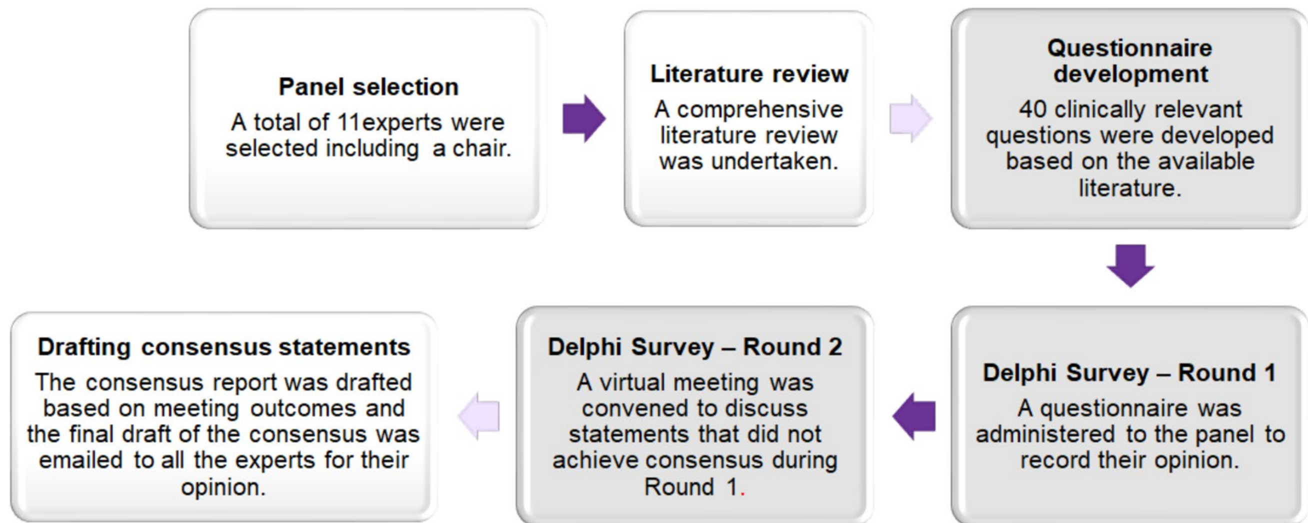

Fig. 1 Overview of the consensus process used to develop the clinical consensus statement

fluids," "fluids," "dehydration," "energy," "non-diarrheal illnesses," "burden," "assessment," "management," "Diabetes," "Sustained release," and "oral rehydration" along with appropriate variations in search phrases and Boolean operators (AND, OR). The included sources comprised randomized controlled trials, case reports, practice guidelines, consensus recommendations, surveys, systematic literature reviews, and meta-analyses. Research studies involving animals or published in a language other than English were excluded. Replicates were eliminated during the filtering process.

Development of questionnaire

After an extensive search, a total of 40 clinically relevant questions were drafted to facilitate the discussion. A modified Delphi consensus was considered to arrive at a consensus [12]. The questionnaire was divided into four major domains:

- Burden of FEE deficits in PWDs
- Assessment of FEE deficits in PWDs
- Role of FEE management in the recovery of T2DM
- Importance of sustained energy concepts in meeting the energy requirements of T2DM

Certain open-ended and discussion questions were incorporated to gather valuable insights from the experts. An electronic survey link to these questions was sent to all the participants to record their views (Delphi survey Round 1).

Consensus process

The level of consensus was categorized as "Yes" (when ≥ 70% of participants agree/strongly agree or disagree/strongly disagree with a statement) and "No" (when < 70% of participants agree/strongly agree or disagree/strongly disagree with a statement) [13] (Table 3). A virtual meeting was held to review the Round 1 Delphi survey results, open-ended questions, and statements that did not attain consensus during Round 1. A Round 2 survey was conducted to discuss questions/statements that did not achieve consensus during the first round of discussion. The consensus report was drafted based on the meeting

Table 3 Level of consensus

Consensus	Definition
Yes	When ≥ 70% of participants agree/strongly agree or disagree/strongly disagree with a statement
No	When < 70% of participants agree/strongly agree or disagree/strongly disagree with a statement

outcomes, and the final draft of the consensus was emailed to all the experts for their opinion.

Results

Following the results of the literature search, in total, 40 clinically relevant questions and/or statements (open-ended and survey-type [$N = 7$]; statements [$N = 33$]) were developed and included in the Delphi survey (Table 4).

Discussion

Burden of FEE deficits in PWDs

PWDs frequently experience FEE deficits, making them vulnerable to significant electrolyte imbalances, especially among the elderly and those with renal insufficiency [14, 15]. Non-diarrheal conditions like infections and fever exacerbate FEE deficits, leading to dehydration and further challenging diabetes management [5, 16]. Although evidence suggests that increased water intake can reduce the risk of hyperglycemia and T2DM [17, 18], dehydration in patients with diabetes remains underdiagnosed and often inadequately managed, with an estimated 24%–45% experiencing dehydration [19–21].

Expert's opinion: Prevalence of dehydration and energy deficits in patients with diabetes

- Among 11 experts, 82% found that in their clinical practice, up to 10% of PWDs present with symptoms of dehydration. This suggests that while dehydration is not present in all patients, it is a noticeable issue within PWDs.
- A majority of the experts found that in their clinical practice, nearly 50% of PWDs and nondiarrheal conditions present with symptoms of dehydration and energy deficits.

Factors contributing to dehydration in PWDs

Fluid loss in PWDs can result from various pathophysiological factors or reduced oral intake. Common causes include diuretic overuse, glucocorticoid deficiency, hypothyroidism, antidiuretic hormone imbalance, insufficient fluid intake, hot weather, strenuous exercise, hyperglycemia, alcohol intake, diabetic complications, diarrhea, and vomiting [5]. Certain diabetes medicines, like sodium–glucose cotransporter-2 (SGLT2) inhibitors, metformin, sulfonylureas, and dipeptidyl peptidase-4 inhibitors, can increase electrolyte imbalances and the risk of hypovolemia, especially in older adults and people with declining kidney function [22, 23]. Older adults aged over 75 years frequently experience dehydration when receiving loop diuretics, thiazides, angiotensin-converting enzyme (ACE) inhibitors, angiotensin II receptor blockers (ARBs), and noninsulin antidiabetic combination therapy [24]. This dehydration risk may exacerbate complications such as DKA, as observed in a study of 110 patients with diabetes, where vomiting (in 50%) and infections (in 52%) were leading triggers for DKA. Predictors of mortality in DKA included insulin needs, fever, and fluid and electrolyte requirements [25]. Additionally, dehydration, whether due to low water intake or elevated vasopressin levels, can worsen glucose dysregulation and raise diabetes risk [26]. A pilot study on nine males with diabetes showed that 3 days of water restriction led to hypohydration and impaired serum glucose regulation [27].

Expert's Opinion: Factors Contributing to Dehydration in PWDs

- The factors that may potentially increase the risk of dehydration in PWDs are the following:

  • Increased fluid loss due to hypoglycemia-induced osmotic stress
  • Side effects of antidiabetes medications (e.g., SGLT2 inhibitors)
  • Thiazide diuretics for hypertension
  • Reduced fluid intake due to fear of frequent urination
  • Insensible fluid loss (e.g., due to fever, respiratory infections, viral fevers, heat illnesses, and dry environment)
  • Exacerbation of urinary/genital tract infections

- SGLT2 inhibitors contribute to an increased risk of dehydration and hypovolemia with increased estimated glomerular filtration rate and advancing age.[14]
- All the experts agreed that while these medications offer benefits for managing diabetes, patient education is essential to minimize the risk of dehydration and its associated complications.

Table 4 Summary of consensus statements

No	Consensus statements	Round 1	Round 2
	Burden of FEE deficits in PWDs		
1	Diabetes in elderly patients aggravates the risk of dehydration	91%	NA
2	Non-diarrheal conditions (e.g., fever, infections, heat-related illnesses, nausea and vomiting, etc.) in PWDs further increase the risk of FEE deficits	100%	NA
3	Non-diarrheal conditions in persons with prediabetes further increase the risk of FEE deficits	73%	NA
4	Dehydration increases the risk of poor glycemic control in PWDs	100%	NA
5	The factors that may potentially contribute to dehydration in PWDs are:	91%	NA
	a) Increased fluid loss due to hypoglycemia-induced osmotic stress	64%	82%
	b) Side effects of anti-diabetes medications (e.g., SGLT2 inhibitors)	73%	NA
	c) Thiazide diuretics for hypertension	82%	NA
	d) Reduced fluid intake due to fear of frequent urination	100%	NA
	e) Insensible fluid loss (e.g., due to fever, respiratory infections, viral fevers, heat illnesses, and dry environment)	82%	NA
	f) Exacerbation of urinary/genital tract infections		
6	Fever in PWDs aggravates the risk of overt or subclinical dehydration (fluid and electrolyte deficits), along with increased energy requirements	100%	NA
7	Infections in PWDs aggravate the risk of overt or subclinical dehydration (fluid and electrolyte deficits), along with increased energy requirements	91%	NA
8	T2DM is associated with a significantly greater risk of heat-related illnesses and complications during heat waves	82%	NA
9	Heat-related illnesses in PWDs aggravate overt or subclinical dehydration (fluid and electrolyte deficits), along with increased energy requirements	91%	NA
10	PWDs and non-diarrheal conditions have increased energy requirements due to heightened metabolic demand and anorexia	91%	NA
	Assessment of FEE deficits in PWDs		
11	Screening PWDs for non-diarrheal dehydration is often overlooked in clinical practice	91%	NA
12	PWDs should be screened for dehydration as a part of routine care	91%	NA
13	PWDs and non-diarrheal conditions should be screened for dehydration and energy requirement as a part of clinical assessment	100%	NA
14	Inadequate FEE management in PWDs can lead to several complications, including the following:	91%	NA
	a) Poor glycemic control	100%	NA
	b) Delayed recovery from acute non-diarrheal illnesses	100%	NA
	c) Increased hospitalization rates	91%	NA
	d) Exacerbation of urinary tract/genital infections	82%	NA
	e) Increased risk of DKA		
15	FEE deficits in PWDs significantly impact their recovery from acute non-diarrheal illnesses	100%	NA
16	FEE deficits in persons with prediabetes significantly impact their recovery from acute non-diarrheal illnesses	91%	NA
	Role of FEE management in the recovery of T2DM		
17	Only plain water recommendations should be avoided in PWDs and non-diarrheal conditions	91%	NA
18	Certain homemade or traditional remedies, such as coconut water and fruit juices, may not be suitable for individuals with diabetes and non-diarrheal conditions	100%	NA
19	Addressing FEE deficits with electrolyte drinks containing slow-release carbohydrates should be recommended from day 1 of non-diarrheal illness in PWDs	91%	NA
20	RTD oral FEE with sustained release energy should be recommended to support recovery in PWDs experiencing fever, infections, heat-related illnesses, or vomiting	100%	NA
21	Oral rehydration recommendations in dehydrated PWDs can help improve glycemic control and enhance overall health outcomes	100%	NA
22	RTD electrolyte drinks with an optimal amount of glucose and sodium promote faster water absorption compared to zero-sugar electrolyte drinks	100%	NA
23	RTD electrolyte drinks with sustained energy can lead to faster recovery in PWDs with non-diarrheal conditions, compared to homemade fluids, coconut water, or fruit juices	100%	NA
24	RTD electrolyte drinks with sustained energy can lead to faster recovery in prediabetic individuals with non-diarrheal conditions, compared to homemade fluids, coconut water, or fruit juices	91%	NA
25	RTD electrolyte drinks with optimal electrolyte, sodium, and glucose concentrations may be a more effective choice for rehydration in PWDs compared to non-RTD options such as homemade fluids, coconut water, or fruit juices	100%	NA

Table 4 (continued)

No	Consensus statements Burden of FEE deficits in PWDs	Round 1	Round 2
26	Electrolyte drinks with low GI should be preferred to address hydration and energy needs in PWDs experiencing non-diarrheal conditions such as fever, infections, health illnesses, and vomiting	100%	NA
27	Well-hydrated patients with diabetes are more likely to recover faster from various infections compared to those who are dehydrated	100%	NA
	Importance of sustained energy concepts in meeting the energy requirements of T2DM		
28	HCPs need to ensure low-glycemic variability and stable insulin levels while managing hydration and energy requirements in PWDs and non-diarrheal conditions	100%	NA
29	Slow-release carbohydrates like isomaltulose, D-tagatose, and trehalose are a preferred source of energy among all available low-glycemic carbohydrates for PWDs, prediabetes, obesity, or those following a healthy diet	91%	NA
30	RTD formulations combining electrolytes and slow-release carbohydrates, such as isomaltulose, D-tagatose, and trehalose, are an effective choice for restoring hydration, addressing energy deficits, and supporting recovery in PWDs experiencing acute non-diarrheal illnesses	91%	NA
31	RTD formulations combining electrolytes and slow-release carbohydrates, such as isomaltulose, D-tagatose, and trehalose, are an effective choice for restoring hydration, addressing energy deficits, and supporting recovery in persons with prediabetes experiencing acute non-diarrheal illnesses	82%	NA
32	Slow-release carbohydrates, such as isomaltulose, D-tagatose, and trehalose, can be packaged in RTD formats with electrolytes to meet hydration and energy needs and support recovery in diabetes and non-diarrheal conditions	100%	NA
33	Slow-release carbohydrates, such as isomaltulose, D-tagatose, and trehalose, can be packaged in RTD formats with electrolytes to meet hydration and energy needs and support recovery in persons with prediabetes and non-diarrheal conditions	91%	NA

DKA, diabetic ketoacidosis; *FEE*, fluid, electrolyte, and energy; *GI*, glycemic index; *HCP*, healthcare professional; *NA*, not applicable; *PWDs*, persons with diabetes; *RTD*, ready-to-drink; *SGLT2*, sodium–glucose cotransporter 2; *T2DM*, type 2 diabetes mellitus

- Patients on SGLT2 inhibitors should be advised to increase their daily water intake by 2–3 glasses to compensate for the increased urination caused by these medications.
- Fatigue and low energy levels may not always be attributed to hyperglycemia; rather, they may be early signs of dehydration, underscoring the role of hydration in enhancing treatment outcomes.

Expert's Opinion: Challenges in Accurately Assessing Dehydration in PWDs

- Subtle signs of early dehydration, such as muscle cramps, dizziness, and fatigue, are often overlooked, especially during seasonal changes
- Overlapping symptoms with hyperglycemia (e.g., thirst and dry mouth)
- Lack of clear clinical markers specific to diabetes-related dehydration
- Inconsistent patient self-reporting of fluid intake
- Reliance on subjective symptoms rather than objective measures
- Lack of consensus on definition and diagnosis

Assessment of dehydration in PWDs

Assessing hydration status in patients with diabetes is challenging due to the complex dynamics of fluid regulation. Accurate hydration assessment is essential, as both overestimation and underestimation can negatively impact patient outcomes [28]. Common dehydration scales, such as the World Health Organization (WHO) scale, Clinical Dehydration Scale, and Gorelick Scale, lack validation for patients with diabetes, highlighting the need for a more tailored approach [29]. While individual signs of dehydration like skin turgor and sunken eyes may be unreliable, combining multiple clinical signs with plasma and urine markers can improve accuracy [30, 31]. Practical, noninvasive markers, such as urine osmolality, specific gravity, and color, are useful in large-scale assessments, though different markers may better suit specific cohorts or dehydration types [32–35].

Expert's Opinion: Commonly Used Parameters for Dehydration Assessment

- Clinical signs and symptoms
- Urine output/quantity
- Urine frequency
- Urine color
- Fluid intake
- Fluid balance charts

- Some experts believed that hematocrit and lactate are the simplest ways to assess dehydration.

However, several barriers exist for accurately assessing dehydration in PWDs. Time constraints, lack of formal

hydration protocols, poor reliability on clinical signs, and insufficient training contribute to inconsistent dehydration management [36, 37].

Diabetes and heat-related illness

PWDs are more at risk of developing heat-related illnesses due to impaired vasodilation and eccrine sweating, which are essential for thermoregulation. Reduced eccrine sweating in these patients is a result of both peripheral and central changes, including decreased sweat gland output, reduced nerve density, limited nitric oxide bioavailability, and disruptions in the sympathetic nervous system, further compromising the body's thermoregulatory capacity. Vasodilatory impairment results from both endothelium-dependent and endothelium-independent mechanisms. Endothelium-dependent vasodilation is hindered by the buildup of advanced glycosylated end products and reduced nitric oxide limits, while endothelium-independent pathways are hindered by vascular changes, such as atherosclerosis and hyperglycemia. Additionally, the absence of C-peptide exacerbates these vasodilatory issues, reducing skin blood flow and impairing body temperature regulation under heat stress. Collectively, these factors contribute to a decreased ability to dissipate heat, making PWDs more vulnerable to heat stress and related illnesses, especially during high-temperature conditions [38]. Consequently, individuals with T2DM face up to 18% increased risk of mortality and 10% higher risk of morbidity during heat waves [39].

Complications due to inadequate FEE management in PWDs

Dehydration in elderly individuals (with or without diabetes), particularly with concurrent infections, correlates with increased morbidity and mortality, leading to higher healthcare resource utilization [40]. Common symptoms, including hypotension, dry and sunken eyes, dizziness, confusion, and lethargy, often result from FEE imbalances.

Expert's Opinion: The Critical Role of FEE Management in Reducing Diabetes-Related Complications

- Inadequate FEE management in PWDs can lead to several complications, including the following:

  a) Poor glycemic control
  b) Delayed recovery from acute nondiarrheal illnesses
  c) Increased hospitalization rates
  d) Exacerbation of urinary tract/genital infections
  e) Increased risk of DKA

- Inadequate FEE management in PWDs can also lead to complications such as acute kidney injury and worsening of preexisting illnesses such as chronic kidney disease (CKD) and stroke.

FEE management in the recovery of T2DM

Effective FEE management is essential for promoting recovery in PWDs or those who are prediabetic, especially during acute non-diarrheal illnesses [5]. Electrolytes are vital for cellular function and become depleted during dehydration episodes, often requiring targeted supplementation.

Current diabetes management guidelines focus primarily on diet and glycemic control, offering limited recommendations on FEE management specifically tailored for diabetes-related dehydration (Table 5).

Despite the availability of these national and international guidelines for diabetes management, there are significant gaps in the recommendations for FEE management in PWDs, especially in the context of dehydration. One key gap is the absence of targeted advice that leaves persons with diabetes vulnerable to issues stemming from electrolyte imbalances. Additionally, most guidelines do not emphasize the importance of addressing energy needs alongside hydration, such as incorporating slow-release carbohydrates to provide a sustained source of energy and stabilize blood glucose levels, particularly during periods of mild illness or recovery. Another critical gap is the lack of guidance

Table 5 Current guidelines and recommendations for dehydration and oral FEE management

Guidelines	Recommendations
RSSDI-ESI (India) [41]	• Emphasizes dietary management for diabetes; no specific hydration or electrolyte guidance
ADA [42]	• Encourages water intake over sugary beverages to manage dehydration • Focuses on glycemic control and diet; general recommendations on hydration but no detailed dehydration guidelines
The European Food Safety Authority [43]	• Average daily intake of water of 1.6 L/6.5 cups per day for women and 2 L/8.5 glasses per day for men
ICMR-NIN (India) [44]	• 2 L/day for healthy adults and increased water intake for the elderly to avoid dehydration

ADA, American Diabetes Association; *ICMR-NIN*, Indian Council of Medical Research-National Nutrition of Institution; *RSSDI-ESI*, Research Society for the Study of Diabetes in India-Endocrine Society of India

on using ready-to-drink (RTD) formulations. Given these gaps in current diabetes management guidelines, it becomes essential to identify strategies that address both hydration and energy needs in persons with diabetes.

Oral rehydration therapy (ORT) is widely regarded as the first-line intervention for managing fluid and electrolyte deficits, and it plays an especially critical role in diabetic care. While oral rehydration solutions (ORS) are generally prescribed for dehydration, the inclusion of glucose as an energy source in FEE solutions can raise concerns about increased osmolarity, which may exacerbate osmotic diarrhea [5]. Differentiating between FEE and traditional ORS solutions enables clinicians to tailor rehydration and energy support to specific dehydration profiles, enhancing treatment efficacy. Evidence suggests that early initiation of oral FEE therapy, ideally from the first day of an acute non-diarrheal illness, and its prompt inclusion in chronic illness management can improve patient outcomes [16]. Additionally, the requirements for managing FEE in patients with prediabetes and diabetes are similar, with both groups needing monitoring of fluid and electrolyte intake to maintain optimal health. Studies support that FEE therapy expedites recovery and shortens illness duration in non-diarrheal conditions [45].

Expert's Opinion: Special Considerations for Diabetes Management

- Elderly men, especially those with prostate conditions, often limit fluid intake to avoid frequent urination. Women tend to reduce fluid intake when traveling to avoid bathroom breaks. Thus, educating patients is crucial to overcoming the barriers associated with dehydration in PWDs.
- Patients on SGLT2 inhibitors should be encouraged to increase their daily water intake by 2–3 glasses to counteract the diuretic effect of these medications.
- A written RTD FEE prescription should be given to facilitate speed of recovery.
- It is vital to educate patients that symptoms such as fatigue and low energy are not always indicative of hyperglycemia; they may often signify dehydration. Recognizing and addressing dehydration early on can prevent misinterpretation and aid in timely

Sustained energy in meeting the energy requirements of type 2 diabetes

Slow-release carbohydrates are increasingly recognized for their role in improving glycemic control by providing glucose gradually, which reduces glycemic variability in T2DM. Unlike high glycemic index (GI) carbohydrates, slow-release options such as isomaltulose, D-tagatose, and trehalose helps minimize postprandial glucose spikes and reduce insulin demand [46, 47]. This further helps to support long-term energy requirements, making these carbohydrates a preferred choice for PWDs and other metabolic conditions.

While isomaltulose has gained recognition for its unique benefits and evidence, other slow-release carbohydrates such as inulin, trehalose, and D-tagatose hold potential in managing glycemic control and providing sustained energy. Inulin supports gut health with minimal glycemic impact, offering potential benefits when paired with other carbohydrates in RTD formulations [48, 49]. D-Tagatose, also known for its low GI and prebiotic properties, increases the amount of short-chain fatty acids through intestinal fermentation, offering protective effects against metabolic diseases. However, potential side effects such as diarrhea and elevated uric acid have been noted, and its high production cost remains a barrier [48].

To further highlight the benefits of slow-release carbohydrates, it is important to compare them with widely available high-GI carbohydrates such as sucrose and maltodextrin. Sucrose, a commonly used sugar, provides rapid energy but leads to significant postprandial glucose spikes and higher insulin demand [47]. Maltodextrin, though frequently included in nutritional supplements, is rapidly digested and absorbed, contributing to high glycemic responses similar to glucose. These characteristics make them less favorable for managing glycemic control in T2DM [50].

In contrast, isomaltulose provides certain benefits as compared to trehalose and D-tagatose. The GI of D-tagatose is quite low, but it can provide only 1.5 kcal energy/g, while trehalose has a high GI of 72. With a GI of 32.8, isomaltulose offers a sustained energy release, and manages insulin levels more effectively than other high-GI alternatives available [46]. Additionally, it improves hormonal responses by lowering gastric inhibitory polypeptide (GIP), increasing glucagon-like peptide-1 (GLP-1), and reducing insulin secretion, and may aid in reducing the risk of long-term complications associated with T2DM. This substitution is also helpful for individuals with impaired glucose tolerance, hypertension, obesity, and older adults. Evidence also suggests significant benefits among Asian populations, where the prevalence of T2DM is high [51].

A study by König et al. investigated the effects of isomaltulose and sucrose on the postprandial metabolic response in 20 overweight or obese men (32–64 years old) with metabolic syndrome and insulin resistance. The ingestion of isomaltulose resulted in lower glycemic and insulinemic responses than sucrose and increased fat oxidation at rest and during physical activity, further underscoring its advantages over traditional high-GI carbohydrates [52]. Slow-release carbohydrates like isomaltulose, D-tagatose, trehalose, and isomaltulose, unlike other alternatives, combine nutritional and physiological benefits with cost-effective production and wide applicability in the food and pharmaceutical industries.

By integrating these slow-release carbohydrates into RTD formulations alongside essential electrolytes, healthcare professionals can offer a holistic approach to managing energy and hydration needs effectively.

RTD FEE formulations are particularly advantageous, as they offer precisely measured electrolytes and energy content, ensuring consistency and accuracy in nutrient intake [5]. An optimal RTD ORT solution for PWDs should incorporate a balanced composition of sweeteners and essential electrolytes, including sodium, potassium, and chloride, to support both hydration and electrolyte balance (Table 6). Using zero-calorie, natural sweeteners like stevia helps manage energy intake, while a precise sodium-to-glucose ratio of 1:1 enhances hydration efficiency by leveraging the sodium–glucose cotransporter-1 (SGLT1) mechanism. This optimal ratio promotes faster water absorption, allowing for rapid rehydration more effectively than water alone.

While traditional remedies, such as homemade sugar-salt solutions, are commonly used for hydration, they often lack consistency and suitability for PWDs as they rely on high-GI sugars, which may contribute to postprandial glucose spikes. In comparison, RTD formulations that combine slow-release carbohydrates with essential electrolytes offer sustained hydration and energy, making them well-suited for diabetes management. Such RTD solutions are beneficial not only for individuals with diabetes but also for those with prediabetes, obesity, or those following a healthy dietary regimen, including older adults managing their hydration and energy needs effectively [46].

The expert panel recommended an optimum combination of electrolytes and slow-release novel carbohydrates, such as isomaltulose, D-tagatose, and trehalose, packaged in the RTD format, which would form an efficient choice to restore hydration and energy deficits and support recovery from acute non-diarrheal illnesses in PWDs and those with prediabetes. Experts also emphasized that when recommending a rehydration fluid for patients with diabetes, especially those with comorbidities, several critical factors must be carefully evaluated. The composition and constitution of the rehydration fluid should be considered based on the patient's diabetes control, renal function, and associated comorbidities. A comprehensive approach is necessary to ensure that fluid, electrolytes, and carbohydrates are provided in a balanced way without compromising overall metabolic control.

Table 6 Key attributes of RTD FEE formulations for diabetes management

Key attributes
• Noncaffeinated, nonalcoholic, and noncarbonated formulation • Hygienically prepared • Optimal levels of key electrolytes such as Na, K, and Cl • Appropriate glucose or dextrose content for faster water absorption • Fully digestible, slow-release carbohydrates to provide sustained hydration and energy

FEE, fluid, electrolyte, and energy; *RTD*, ready-to-drink

Management of dehydration in low resource settings

In resource-limited settings, where challenges in maintaining hydration are more pronounced, educating patients and caregivers to recognize dehydration signs and promoting daily fluid intake are essential. Noninvasive hydration indicators, like urine color, can help patients manage hydration effectively.

Daily fluid intake should be encouraged, with emphasis on locally available options like ORS prepared with water, sugar, and salt, which is an invaluable tool for combating dehydration [53]. Similarly, rice water, a byproduct of boiling rice, is a cost-effective source [54]. Buttermilk, a common household preparation, serves as an excellent hydrating drink, offering electrolytes like sodium and potassium [55]. Coconut water (rich in natural electrolytes) is another valuable option, especially in tropical regions where it is abundantly available [56]. Infused water with herbs like mint or lemon can offer flavor and nutrients, encouraging better hydration adherence. These solutions are simple to prepare and cost-effective, making them practical for widespread use. Other home-prepared options, like sattu (roasted gram flour drink) and lightly salted lemon water, can also support hydration effectively [57, 58].

Additionally, incorporating water-rich foods such as fruits and vegetables can further support hydration. Fruits such as watermelon, papaya, oranges, and apples are excellent low-cost hydration sources. Vegetables like cucumber, tomato, and lettuce are similarly beneficial and can be consumed raw or as part of salads to retain their water content [57, 59]. Vegetable broths and soups can also provide hydration while delivering essential electrolytes and nutrients, benefiting patients managing T2DM [60].

Slow-release carbohydrates, such as those found in whole grains like oats and millets, or starchy vegetables like sweet potatoes, provide sustained energy release and play an essential role in maintaining blood sugar levels, especially in PwDs [61, 62]. Combining these carbohydrate sources with hydrating foods, such as combining porridge with milk or adding fruits like apples, ensures both energy and hydration needs are met effectively.

In regions where RTD (ready-to-drink) formulations are unavailable or unaffordable, these naturally occurring food products play a pivotal role in managing hydration. Highlighting traditional and locally accepted hydration solutions ensures that patients and caregivers have practical, sustainable, and affordable options.

These strategies, focusing on education and community support, provide sustainable solutions for hydration and FEE management in PWDs in resource-limited settings.

Conclusion

Managing FEE balance in PWDs is crucial, especially during illness or increased metabolic demands. Evidence suggests that tailored FEE solutions, particularly those with slow-release carbohydrates, provide a stable energy source while minimizing glycemic fluctuations, making them superior to standard hydration methods like ORS. Despite the benefits of FEE solutions, current diabetes guidelines lack specific hydration and energy recommendations for patients with T2DM. Integrating personalized FEE strategies into clinical guidelines could bridge this gap, helping to prevent dehydration-related complications and supporting better overall glucose control.

Effective hydration management faces additional challenges by patient reluctance toward commercially available rehydration drinks and the lack of standardized hydration assessment protocols. Educating PWDs on the importance of personalized hydration strategies and simple hydration monitoring methods, such as using urine color, can empower self-management. Encouraging fluid intake between meals and implementing standardized hydration assessment checklists, along with staff training on dehydration signs, can improve care delivery. Additionally, exploring RTD FEE beverages tailored to T2DM needs offers potential for enhanced recovery and reduced healthcare costs.

Addressing these gaps requires improving physician knowledge, raising patient awareness, and implementing standardized protocols. These steps can ensure effective hydration management, reduce complications, and enhance the overall quality of life for PWDs.

Acknowledgment All authors contributed to the development and review of this Delphi consensus and confirm that they have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. All authors met ICMJE criteria, and those who fulfilled those criteria were enlisted as authors. All authors had access to the study data and made the final decision regarding where to publish these data and approved submission to this journal.

Data availability Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. International Diabetes Federation. IDF Diabetes Atlas, 10th ed. 2021. Available at: https://diabetesatlas.org/data/en/indicators/1. Accessed on: 28th October 2024.
2. Anjana RM, Unnikrishnan R, Deepa M, et al. Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). Lancet Diabetes Endocrinol. 2023;11:474–89.
3. Lee JW. Fluid and electrolyte disturbances in critically ill patients. Electrolyte Blood Press. 2010;8(2):72–81.
4. Albeladi FI, Wahby Salem IM, Albandar AA, Almusaylim HA, Albandar AS. Electrolyte imbalance in infectious disease patients at King Abdulaziz Hospital. Jeddah J Taibah Univ Med Sci. 2021;17(2):256–63.
5. Mohan V, Kalra S, Zargar AH, Tiwaskar M, Thakor P, Malve H. Diabetes mellitus and fluid imbalance: the need for adequate hydration. J Assoc Physicians India. 2024;72(6):16–24.
6. Stoner GD. Hyperosmolar hyperglycemic state. Am Fam Physician. 2005;71(9):1723–30.
7. Karuppan A, Sahay MI, Ravindranathan R, et al. Electrolyte disturbances among diabetic patients admitted in a multi-specialty hospital in southern India. JCDR. 2019;13(2):OC12–OC15.
8. Taylor K, Tripathi AK, Jones EB. Adult Dehydration. 2022 Oct 3. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
9. Liamis G, Liberopoulos E, Barkas F, Elisaf M. Diabetes mellitus and electrolyte disorders. World J Clin Cases. 2014;2(10):488–96.
10. Dhondup T, Qian Q. Acid-base and electrolyte disorders in patients with and without chronic kidney disease: an update. Kidney Dis (Basel). 2017;3(4):136–48.
11. Maklad SF, Basiony F. Electrolyte disturbances in patients with acute exacerbation of chronic obstructive pulmonary disease. The Scientific Journal of Al-Azhar Medical Faculty, Girls. 2019;3(2):427–31.
12. Nasa P, Jain R, Juneja D. Delphi methodology in healthcare research: How to decide its appropriateness. World J Methodol. 2021;11(4):116–29.
13. Lazzarini PA, Raspovic A, Prentice J, Commons RJ, Fitridge RA, Charles J, Cheney J, Purcell N, Twigg SM; Australian Diabetes-related Foot Disease Guidelines & Pathways Project. Guidelines development protocol and findings: part of the 2021 Australian evidence-based guidelines for diabetes-related foot disease. J Foot Ankle Res. 2022 Apr 19;15(1):28.
14. Khanduker S, Ahmed R, Khondker F, et al. Electrolyte disturbances in patients with diabetes mellitus. Bangladesh J Med Biochem. 2018;10(1):27–35.
15. Soni NK, Shankar V. Comparison of electrolytes in diabetic and non-diabetic patients. Int J Med Biomed Stud. 2020;4(6):273–5.
16. Reddy BR, Nigam A, Gogia A, et al. Oral fluid, electrolytes, and energy management in various adult and geriatric illnesses beyond diarrhea: An Indian expert panel Delphi consensus recommendation. J Assoc Physicians India. 2024;72(6S):39–56.
17. Roussel R, Fezeu L, Bouby N, et al. Low water intake and risk for new-onset hyperglycemia. Diabetes Care. 2011;34(12):2551–4.
18. Janbozorgi N, Allipour R, Djafarian K, et al. Water intake and risk of type 2 diabetes: a systematic review and meta-analysis of observational studies. Diabetes Metab Syndr. 2021;15(4):102156.
19. El-Sharkawy AM, Watson P, Neal KR, et al. Hydration and outcome in older patients admitted to hospital (the HOOP prospective cohort study). Age Ageing. 2015;44(6):943–7.
20. Shells R, Morrell-Scott N. Prevention of dehydration in hospital patients. Br J Nurs. 2018;27(10):565–9.

21. Parkinson E, Hooper L, Fynn J, et al. Low-intake dehydration prevalence in non-hospitalised older adults: systematic review and meta-analysis. Clin Nutr. 2023;42(8):1510–20.
22. Filippatos T, Tzavella E, Rizos C, et al. Acid-base and electrolyte disorders associated with the use of antidiabetic drugs. Expert Opin Drug Saf. 2017;16(10):1121–32.
23. Rong X, Zhu Y, Wen B, et al. Risk of hypovolemia associated with sodium-glucose cotransporter-2 inhibitors treatment: a meta-analysis of randomized controlled trials. Front Cardiovasc Med. 2022;9:973129.
24. Goldman A, Fishman B, Twig G, et al. The real-world safety profile of sodium-glucose co-transporter-2 inhibitors among older adults (≥ 75 years): a retrospective, pharmacovigilance study. Cardiovasc Diabetol. 2023;22(1):16.
25. Mahesh MG, Shivaswamy RP, Chandra BS, *et al*. The study of different clinical pattern of diabetic Ketoacidosis and common precipitating events and independent mortality factors. *J Clin Diagn Res*. 2017;11(4):OC42– OC46.
26. Jansen LT, Suh H, Adams JD, et al. Osmotic stimulation of vasopressin acutely impairs glucose regulation: a counterbalanced, crossover trial. Am J Clin Nutr. 2019;110(6):1344–52.
27. Johnson EC, Bardis CN, Jansen LT, et al. Reduced water intake deteriorates glucose regulation in patients with type 2 diabetes. Nutr Res. 2017;43:25–32.
28. El-Sharkawy AM, Sahota O, Lobo DN. Acute and chronic effects of hydration status on health. Nutr Rev. 2015;73(Suppl 2(suppl 2)):97–109.
29. Falszewska A, Szajewska H, Dziechciarz P. Diagnostic accuracy of three clinical dehydration scales: a systematic review. Arch Dis Child. 2018;103(4):383–8.
30. Deißler L, Wirth R, Frilling B, et al. Hydration status assessment in older patients. Dtsch Arztebl Int. 2023;120(40):663–9.
31. Garrett DC, Rae N, Fletcher JR, et al. Engineering approaches to assessing hydration status. IEEE Rev Biomed Eng. 2018;11:233–48.
32. Kavouras SA. Assessing hydration status. Curr Opin Clin Nutr Metab Care. 2002;5(5):519–24.
33. Barley OR, Chapman DW, Abbiss CR. Reviewing the current methods of assessing hydration in athletes. J Int Soc Sports Nutr. 2020;17(1):52.
34. Baron S, Courbebaisse M, Lepicard EM, et al. Assessment of hydration status in a large population. Br J Nutr. 2015;113(1):147–58.
35. Bak A, Tsiami A, Greene C. Methods of assessment of hydration status and their usefulness in detecting dehydration in the elderly. Curr Res Nutr Food Sci J. 2017;5(2):43–54.
36. Koves IH, Neutze J, Donath S, et al. The accuracy of clinical assessment of dehydration during diabetic ketoacidosis in childhood. Diabetes Care. 2004;27(10):2485–7.
37. Reddy BR, Sreenivasamurthy L, Pal J, et al. Association of physicians of India expert recommendations on oral fluid, electrolytes, and energy management during transition care and discharge for hospitalized patients with nondiarrheal illnesses. J Assoc Physicians India. 2024;72(6S):57–66.
38. Kenny GP, Sigal RJ, McGinn R. Body temperature regulation in diabetes. Temperature. 2016;3(1):119–45.
39. Moon J. The effect of the heatwave on the morbidity and mortality of diabetes patients; a meta-analysis for the era of the climate crisis. Environ Res. 2021;195(110762):110762.
40. Malve H, Sathe P, Chakravarty P, et al. Knowledge, attitudes, and practices regarding oral fluid, electrolyte, and energy management in acute nondiarrheal illnesses among physicians in India. J Assoc Physicians India. 2023;71(5):11–2.
41. Chawla R, Madhu SV, Makkar BM, et al. Correction to: RSSDI-ESI Clinical Practice Recommendations for the Management of Type 2 Diabetes Mellitus 2020. *Int J Diabetes Dev Cntries* (July-September 2020). 2020;40(3):460.
42. American Diabetes Association; 5. Lifestyle Management: *Standards of Medical Care in Diabetes—2019*. *Diabetes Care*.2019; 42 (Supplement_1): S46–S60.
43. EFSA Panel on Dietetic Products N, and Allergies (NDA). Scientific opinion on dietary reference values for water. *EFSA J*. 2010;8(3):1459.
44. Nutrition NIo. Dietary Guidelines for Indians - A Manual 2011. Available at: http://www.nin.res. in/downloads/DietaryGuidelinesforNINwebsite. pdf. Accessed on: 13 November 2024.
45. Sathe P, Chakravarty P, Tesado C, et al. Comparing the knowledge, attitude, and practices on oral fluids, electrolytes, and energy management in non-diarrheal illnesses across different physician specialties in India. J Assoc Physicians India. 2023;71(10):19–30.
46. Kokubo E, Morita S, Nagashima H, et al. Blood glucose response of a low-carbohydrate oral nutritional supplement with isomaltulose and soluble dietary fiber in individuals with prediabetes: a randomized, single-blind crossover trial. Nutrients. 2022. https://doi.org/10.3390/nu14122386.
47. Keyhani-Nejad F, Kemper M, Schueler R, et al. Effects of palatinose and sucrose intake on glucose metabolism and incretin secretion in subjects with type 2 diabetes. Diabetes Care. 2016;39(3):e38–9.
48. Sokołowska E, Sadowska A, Sawicka D, et al. A head-to-head comparison review of biological and toxicological studies of isomaltulose, d-tagatose, and trehalose on glycemic control. Crit Rev Food Sci Nutr. 2022;62(21):5679–704.
49. Kordowski A, Künstner A, Schweitzer L, et al. PalatinoseTM (isomaltulose) and prebiotic inulin-type fructans have beneficial effects on glycemic response and gut microbiota composition in healthy volunteers—a real-life, retrospective study of a cohort that participated in a digital nutrition program. Front Nutr. 2022;9:829933.
50. Stevenson EJ, Watson A, Theis S, et al. A comparison of isomaltulose versus maltodextrin ingestion during soccer-specific exercise. Eur J Appl Physiol. 2017;117:2321–33.
51. Xie J, Li J, Qin Q, et al. Effect of isomaltulose on glycemic and insulinemic responses: a systematic review and meta-analysis of randomized controlled trials. Adv Nutr. 2022;13(5):1901–13.
52. König D, Zdzieblik D, Holz A, et al. Substrate utilization and cycling performance following Palatinose™ ingestion: a randomized, double-blind, controlled trial. Nutrients. 2016;8(7):390.
53. Oral Rehydration salts. Available at: https://www.who.int/publications/i/item/WHO-FCH-CAH-06.1. Accessed on: 27 November 2024.
54. Fontaine O, Gore SM, Pierce NF. Rice-based oral rehydration solution for treating diarrhoea. *Cochrane Database of Systematic Reviews.* 1996;2005(3).
55. Barukčić I, Jakopović KL, Božanić R. Whey and buttermilk—Neglected sources of valuable beverages. *Natural beverages.* 2019; 209–242.
56. Chaubey A, Sharma M, Bhatnagar B. Comparitive study on coconut water, carbohydrate electrolyte sports drink and sodium enriched coconut drink on measures of hydration and physical performance in athletes. IOSR Journal of Sports and Physical Education. 2017;4(03):46–51.
57. RSSDI. Management of diabetes : meal plans and nutrition (For people with diabetes and their families). Available at: https://

rssdi.in/newwebsite/journal/1989_october/diab_edu_prog.pdf. Accessed on: 09 January 2025.

58. Kaur R, Prasad K. Development and characterization of chickpea based ready to use replacement beverage mix. Food Measure. 2024;18:3595–618.
59. Sharp RL. Role of whole foods in promoting hydration after exercise in humans. J Am Coll Nutr. 2007;26(sup5):592S-S596.
60. Fernández-López J, Botella-Martínez C, Navarro-Rodriguez de Vera C, *et al.* Vegetable soups and creams: Raw materials, processing, health benefits, and innovation trends. P*lants*. 2020;9(12):1769.
61. Jenkins DJ, Wolever TM, Taylor RH, et al. Slow release dietary carbohydrate improves second meal tolerance. Am J Clin Nutr. 1982;35(6):1339–46.
62. Vinoy S, Laville M, Feskens EJ. Slow-release carbohydrates: growing evidence on metabolic responses and public health interest. Summary of the symposium held at the 12th European Nutrition Conference (FENS 2015). *Food Nutr. Res.* 2016;60(1):31662.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.