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Navigating sports nutrition: athlete and coach experiences from a 16-week personalized intervention

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Abstract

Background Athletes in Sri Lanka face significant barriers when attempting to adhere to sports nutrition recommendations (SNR), despite the potential for these strategies to optimize performance. This study examines the perceptions and experiences of athletes and coaches regarding barriers and challenges to nutrition interventions in the context of a resource-limited environment.

Methods In-depth interviews with 15 track and field athletes and their coaches, who completed a 16-week personalized sports nutrition intervention, were analyzed using reflexive thematic analysis with NVIVO v10.0. A data-driven, inductive approach to coding was employed, allowing themes to emerge organically from the data rather than being pre-determined by existing frameworks. Thematic analysis followed an iterative process of familiarization, open coding, theme refinement, and synthesis.

Results The athletes had a mean age of 23.4 ± 2.8 years. The four male coaches had a mean age of 50.4 ± 6.41 years. Three key themes were identified: (I) Intrinsic challenges, (II) Extrinsic challenges faced by athletes, and (III) Recommendations and insights to improve the efficiency of the sports nutrition intervention. We identified financial constraints, knowledge gaps, and taste preferences as intrinsic challenges, while residential limitations and other practical difficulties—such as limited access to recommended foods, time management challenges, barriers to adhering to meal timings, and psychosocial stressors—were identified as extrinsic challenges. Key insights for improvement included increasing the frequency of consultations and involving coaches in these consultations, enabling them to actively support athletes in adhering to nutritional recommendations. Athletes expressed a preference for guidelines in both printed and digital formats. Participants also emphasized the need for enhanced medical support through more frequent doctor-athlete interactions and investing in young athletes by extending the program to school-level athletes, offering structured guidance, nutritional support, and sustained monitoring to foster long-term success.

Conclusions Personalized sports nutrition interventions in Sri Lanka are hindered by multifaceted barriers, but opportunities for transformative change exist through collaboration among athletes, coaches, sports organizations, and policymakers. A systems-oriented approach, addressing both individual and structural challenges, is essential for improving adherence to nutritional recommendations.

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Introduction

Sporting performance is significantly influenced by nutrition, yet athletes respond differently to the same foods, nutrients, and supplements [1]. Consequently, personalized nutrition has become essential for optimizing health, body composition, and athletic performance outcomes by tailoring dietary recommendations to an individual's specific training and competition demands, health status, body composition, and lifestyle factors [2]. This personalized approach recognizes that food choices are complex and shaped by an interplay between a person's self-concept and daily eating habits [3]. Various factors, including nutrition knowledge, attitudes, and sociodemographic characteristics, can further shape one's dietary perceptions and practices among athletes [4].

Despite the critical role of personalized sports nutrition, research over the past decade has shown that many athletes fail to meet recommended guidelines for energy and carbohydrate intake [5]. More recently, there has been concern about the impact of body composition goals on dietary intake and nutritional perceptions within the athletic community [6]. Cultural and peer pressures in sports can further drive athletes toward unsustainable dietary practices aimed at meeting performance standards. This is influenced by the "performance logic" that permeates the athlete's ethos, where eating behaviours are often dictated by the pursuit of peak performance rather than balanced nutrition. Additionally, the concept of "nutritionism" underscores how athletes may focus narrowly on isolated nutrients or dietary components, sometimes overlooking the broader picture of overall health, which can lead to distorted relationships with food and eating [6]. Consequently, it is essential that sports nutrition interventions (SNI) not only focus on initial planning but also integrate continuous monitoring, evaluation, and adaptation to ensure sustained adherence. Evidence-based practitioners and researchers must continuously monitor athletes' adherence and compliance. Given the pivotal role of the coach-athlete relationship in both team and individual sports [7], coaches should be actively included in qualitative assessments of adherence and compliance with nutrition interventions, with the dietitian/nutritionist primarily responsible for assessing dietary intake and the coach supporting adherence by fostering a positive environment and reinforcing key recommendations [8].

Sri Lanka is currently experiencing significant economic challenges, marked by high inflation and limited access to essential goods [9]. This financial instability affects food availability and affordability, thereby influencing athletes' nutrition choices and limiting the feasibility and effectiveness of personalized sports nutrition interventions in low-income settings. Incorporating these challenges into the context of personalized SNIs is essential for understanding how economic conditions can influence both the feasibility and effectiveness of nutrition interventions.

In examining athletes' perceptions and experiences with SNIs, qualitative research plays a vital role in capturing the nuanced, context-specific experiences that quantitative studies often overlook. By focusing on the subjective experiences of athletes, qualitative research offers valuable insights into the barriers, challenges, and factors influencing the success of sports nutrition interventions. Several earlier studies have been conducted in both team and individual sports contexts, underscoring the importance of this approach [10–12]. Only three studies have specifically addressed the impact of personalized sports nutrition interventions on athletes' performance and well-being. For instance, a qualitative study of elite-level Australian Football players used semi-structured interviews to explore factors influencing dietary intake and food choices [10]. Findings indicated that less experienced players often restricted carbohydrate intake to meet body composition goals, while during the competition season, players prioritized performance, with greater emphasis on carbohydrate intake as matches approached. Additionally, athletes reported that nutrition goals were more achievable when supported by family, coaches, and teammates, and one-on-one consultations with a sports dietitian emerged as the preferred mode of nutritional guidance [10]. Another qualitative study investigating the perspectives of professional track and field athletes and key athletic stakeholders on sports nutrition knowledge (SNK) found that, while athletes generally recognized the importance of proper nutrition for enhancing performance, their opinions on supplementation were divided [12]. Some athletes viewed supplementation as essential for achieving peak performance, citing personal improvements in energy and recovery, while others expressed scepticism, questioning the effectiveness of supplements and preferring to rely on whole foods. The study also identified key barriers to optimizing nutrition, notably highlighting a lack of up-to-date SNK as the primary obstacle. These diverse perspectives demonstrate how qualitative research captures the complexity of athlete experiences, offering a nuanced understanding of the challenges and perceptions surrounding sports nutrition. Similarly, a qualitative study examined college athletes' experiences and perceptions of personalized nutrition plans [11]. Semi-structured interviews revealed that personalized nutrition plans

positively impacted athletes' physical performance on the field or court, while also highlighting the complexities associated with implementing these individualized plans in a collegiate sports environment [11]. Moreover, coaches' support emerged as a critical factor for adherence to nutritional advice, emphasizing the coach-athlete dynamic in the effective implementation of nutrition intervention [11]. Importantly, these studies suggest that while athletes' perceptions offer valuable insights, they may not fully capture the broader influences affecting nutritional adherence and performance, such as coaching strategies, institutional policies, or the availability of professional guidance.

Furthermore, qualitative studies have explored the perspectives of athletes' coaches regarding nutrition and eating habits. A study assessing elite coaches' attitudes toward nutrition highlighted their varying levels of understanding of sports nutrition and their approaches to guiding athletes in their dietary choices [13]. Coaches emphasized the importance of individualized nutrition plans tailored to athletes' needs and performance goals. However, when it comes to addressing more complex issues like eating disorders, a study examining coaches' attitudes toward eating disorders (ED) in female athletes across aesthetic, weight class, and endurance sports revealed that many coaches did not view ED as a significant issue in their sport. Despite having experience working with athletes with ED, they reported challenges in identifying symptoms and highlighted barriers such as athletes' denial, a lack of female colleagues within teams, and limited accessible resources for treatment referrals at both the national sports federation and club levels [13]. Carter and colleagues conducted qualitative research to explore the perspectives of players, sports nutritionists, and coaches regarding the barriers and enablers to adhering to nutritional recommendations within a professional football club. The study identified several common themes related to adherence, including capabilities—such as nutritional knowledge and cooking skills; opportunity—including food provision at training venues, accessibility of nutritionists, and living situations; and motivation—with factors like performance implications and role modelling. The researchers concluded that inadequate food provision both at training and in home, as well as limited time with the sports nutritionist, were key barriers to nutritional adherence, particularly in youth football players [14]. These findings underscore the necessity of integrating both athlete and coach perspectives in research. Athletes are directly impacted by nutrition interventions, yet coaches play a pivotal role in shaping and reinforcing these interventions within training environments. Failing to consider the coach's viewpoint may overlook critical elements influencing an athlete's ability to implement nutrition strategies effectively. Conversely, relying solely on coach perceptions may not fully capture the day-to-day nutritional challenges athletes face, emphasizing the need for a holistic approach that considers both perspectives. Additionally, it is important to acknowledge potential limitations regarding sample size in qualitative research. While smaller samples can provide rich, in-depth insights, they may also limit the generalizability of findings. Thus, a balanced discussion on the sample's representativeness is necessary when interpreting results.

Several studies have examined various aspects of sports nutrition in athletes, focusing on their knowledge, attitudes, and adherence to dietary recommendations. For example, Davis an colleagues [15] examined barriers to adhering to nutrition plans, identifying financial constraints and lack of awareness as major hurdles impeding optimal dietary practices among athletes. Furthermore, a systematic review by Heaney et al. [16] highlighted cultural and environmental factors affecting athletes' ability to follow personalized nutrition plans, pointing to the need for more context-specific research. While many studies have explored athlete perceptions, fewer have examined coaches' perspectives, despite their key role in training and nutrition guidance. Including both viewpoints allows for a more complete understanding of barriers and facilitators in sports nutrition. Coaches shape athletes' eating habits through training schedules, team culture, and direct advice, making their insights valuable for designing effective interventions. On the other hand, focusing only on athletes might overlook logistical challenges coaches face in implementing nutrition strategies. By considering both groups, this study provides a well-rounded perspective on the effectiveness and challenges of a personalized sports nutrition intervention (SNI).

The present study addresses a notable gap in the literature by qualitatively assessing both athletes' and coaches' perceptions and experiences of a 16-week personalized SNI, focusing on its effectiveness and the practical challenges encountered in a low-income context. To date, no published qualitative research has directly explored these perspectives on personalized SNIs. While previous research has examined the effectiveness of SNIs, no published qualitative studies have directly explored how both athletes and coaches perceive and navigate the challenges of implementing such interventions.

Our prior 16-week evidence-based, culturally tailored intervention for Sri Lankan track and field athletes, with procedures published elsewhere [17], demonstrated positive outcomes, yet some participants did not show improvements in areas such as body composition and sports nutrition knowledge. To gain a deeper insight into the inconsistencies observed in outcomes and the practical difficulties faced by athletes, this study examines the lived experiences of both athletes and their coaches, who

play an integral role in the athletes' daily training and nutrition practices. Unlike earlier studies that focused primarily on athletes' quantitative responses to SNIs, this study uniquely investigates the barriers, facilitators, and implementation process from both the athlete and coach standpoint. Coaches play a critical but often overlooked role in shaping athletes' nutrition behaviours, making their perspectives invaluable for designing effective interventions. While a previous study has explored athletes' experiences with the effectiveness of a personalized SNI among Sri Lankan track and field athletes [12] —assessing both qualitative and quantitative improvements in performance—this study uniquely focuses on the barriers and challenges faced by athletes and coaches during the 16-week intervention. Unlike the prior study, which primarily evaluated the perceived effectiveness of the intervention, this research investigates the specific obstacles that hindered adherence and the contextual factors influencing real-world implementation. Rather than framing this as a secondary analysis, this study builds upon previous findings by offering a holistic, stakeholder-informed evaluation of a personalized, evidence-based, and culturally specific SNI in a low-resource sports environment. To achieve this, the study explicitly aims to explore the experiences of both athletes and coaches regarding the implementation of a 16-week, personalized, evidence-based, and culturally specific sports nutrition intervention in a low-resource setting, identify barriers and challenges affecting adherence to nutritional recommendations, and evaluate the process of intervention implementation.

Methods

Study participants and design

Elite and highly trained track and field athletes, along with their respective coaches, were recruited from a national-level athletic pool to assess the perceived impact of the personalized SNI. The recruitment process was by a trained research assistant (KW) who assisted in contacting eligible athletes and coaches. All participants were aged between (18–30 years), and all athletes were required to have successfully completed a 16-week RCT of an evidence-based, culturally accepted, personalized SNI, which is detailed elsewhere [11]. This intervention provided individualized nutritional guidance through one-on-one sessions at baseline, the 4th, and 8th weeks. It covered key dietary aspects such as energy balance, macronutrient distribution, micronutrient adequacy, hydration, and the use of evidence-based ergogenic aids, ensuring alignment with international sports nutrition guidelines. Nutritional strategies were tailored to each athlete's sports discipline and cultural dietary habits to optimize performance and recovery. The nutritional guidance throughout the intervention was led by a medically qualified clinical nutritionist (RJ).

Eligibility criteria included national or international competition experience and full-time athletic status, with athletes actively engaged in competitive track and field at the national or international level and possessing substantial training experience. Coaches were required to have extensive experience in training elite or highly trained track and field athletes. Recruitment was voluntary, with informed written consent obtained by the principal investigator after explaining the study details in the participants' native language. Informed written consent was obtained from each participant after providing a comprehensive explanation of the study's objectives, methods, and potential benefits. As all participants were adults, parental consent was not required. All procedures adhered to the Declaration of Helsinki, and ethical approval for this qualitative study was obtained by the Institutional Ethical Review Committee, Faculty of Medicine, University of Peradeniya, Sri Lanka (Reference: 2024/EC/21).

To ensure diverse perspectives and maximize representativeness, purposive sampling was used, selecting athletes and coaches from different event specializations (sprints, middle distance, long distance, jumps, and throws). Additionally, efforts were made to include both male and female athletes to capture gender-based variations in experiences. To ensure comprehensive and transparent reporting, this study followed the SRQR (Standards for Reporting Qualitative Research) guidelines [18] to detail all aspects of the methodology.

Data collection

Data were collected through face-to-face, computer-mediated, in-depth interviews conducted via Zoom Video Communications, Inc. (California, USA) using a pre-designed interview guide. The interview questions were formulated based on insights gained from our two earlier qualitative studies [12, 19]. This ensured that the questions were highly relevant to the context and experiences of Sri Lankan track and field athletes and coaches. A pilot study was conducted with a small group of accessible athletes from the same category to refine the clarity and feasibility of the questions. No major modifications were necessary following the pilot, confirming the appropriateness of the interview guide. The interview questions were semi-structured, designed to elicit in-depth responses across key topics such as adherence, barriers, and suggested improvements for the 16-week personalized sports nutrition intervention. The guide (attached as supplementary file 1) included open-ended main questions to explore participants' perceptions and experiences, followed by targeted probes to encourage further elaboration on specific aspects such as logistical

challenges, financial constraints, personal dietary preferences, and the role of coach involvement.

A trained research assistant (KW) conducted the interviews using semi-structured, open-ended questions to maintain consistency while allowing flexibility in responses and ensuring the overall consistency of the interview process. Another trained research assistant attended each interview as an observer alongside the facilitator (RP), noting key comments relevant to the discussion. RP was responsible for guiding the interviews, maintaining focus, stimulating constructive discussion, ensuring adherence to time constraints, and maintaining a neutral stance throughout. At the end of each session, RP and KW summarized the key points from the interview.

The interviews focused on three key themes: (I) Intrinsic challenges, (II) Extrinsic challenges faced by athletes, and (III) Recommendations and insights to improve the efficiency of the SNI. These themes were derived based on insights from previous qualitative studies [12, 20] and were further refined through a pilot study conducted with a subset of athletes. The interview guide (Supplementary File 1) was designed to explore participant experiences with adherence, barriers, and practical challenges in implementing the intervention. Thematic analysis revealed three key themes that emerged organically from participants' responses, capturing both internal and external factors influencing adherence and the effectiveness of the SNI. Interviews lasted between 20 min, depending on participant engagement. All sessions were audio-recorded and supplemented with detailed field notes to capture non-verbal cues, contextual information, and additional insights that might not have been explicitly stated by the participants. Participants were encouraged to share real-life examples and specific incidents related to their experiences with the intervention to enrich the depth of the data.

Data analysis and rigor

A reflexive thematic analysis was conducted to explore participants' experiences, guided by Braun and Clarke's framework [21], which recognizes researcher subjectivity as central to the interpretative process. The analysis followed the structured approach outlined by Naeem et al. [22], beginning with data familiarization through repeated readings of interview transcripts by the research team (RJ, KW, and RP). An open coding process was employed to identify recurring patterns and key concepts, with codes generated inductively while remaining sensitive to the research objectives. These codes were iteratively grouped into potential themes that both reflected the data and aligned with the study's aims.

Preliminary themes were generated and examined to identify overarching patterns that captured participants' core experiences. This involved a reflexive process where researchers engaged in discussions to evaluate the relevance and coherence of each theme in relation to the research questions. Sub-themes within each key theme were identified to further explore specific challenges and insights shared by participants, adding depth and specificity to the broader thematic categories. At this stage, theme development was guided by both inductive and deductive approaches. Emergent themes were cross-checked against the study's research focus to ensure coherence. The refinement of themes followed an inductive approach to ensure interpretations were data-driven rather than predetermined.

The preliminary themes, focusing on intrinsic and extrinsic challenges and recommendations for improving intervention efficiency, were reviewed, and refined iteratively to accurately capture participants' experiences. Each theme was clearly defined and labelled to capture its core meaning before being synthesized into a cohesive narrative. To enhance rigor, relevant participant quotations were integrated to provide illustrative examples and context. The research team documented coding decisions and reflections to enhance transparency and dependability. Following the initial coding process, all three researchers (RJ, KW, and RP) independently coded all transcripts. After this, a subset of transcripts was independently coded by the research team to ensure consistency in coding practices. This subset served as a cross-checking exercise to align coding approaches and resolve any discrepancies. All discrepancies were discussed and resolved through multiple team meetings to ensure consistency and depth in analysis. The collaborative approach ensured that thematic development was not constrained by predefined categories, allowing both structured analysis and the emergence of novel insights.

This study adopted a constructivist epistemology, acknowledging that knowledge is co-constructed through interactions between researchers and participants. Data saturation was used to determine when no new themes or insights were emerging from the interviews, ensuring comprehensive representation of participants' perspectives. Once saturation was reached, further data collection was considered unnecessary to address the research questions. To ensure rigor and trustworthiness, investigator triangulation was employed, where multiple researchers independently coded a subset of transcripts to reduce bias. Regular team discussions were held to compare coding, resolve discrepancies, and refine emerging themes. Reflexivity was maintained by keeping analytical memos and researcher notes, allowing for self-evaluation and acknowledgment of potential biases. Member checking was conducted, where a subset of participants reviewed and confirmed the accuracy of their interview interpretations.

Table 1 Baseline demographic data of athletes

Variable	Athletes ($n=13$) Mean ± SD
Gender	
Male	8 (62%)
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Male	
Female	5 (38%)
Education level: n (%)	
School education level I	5 (38%)
School education level II	6 (46%)
Completed/ enrolled in a degree/diploma	2 (16%)
Sports experience (y)	7.15 ± 3.60
Level of performance: n (%)	5 (38%)
Elite	
Highly trained	8 (62%)
Main sport event: n (%)	
Sprinting	1 (7%)
Middle-distance running	7 (54%)
Long-distance running	3 (23%)
Jumping	2 (16%)

Table 2 Baseline demographic data of coaches

Variable	Coaches ($n=4$) Mean ± SD
Gender	
Age (y)	50.4 ± 6.41
Male	5 (100%)
Female	0 (0%)
Service experience (y)	25.8 ± 6.76
Education level: n (%)	
School education level I	0 (0%)
School education level II	2 (40%)
Completed/ enrolled in a degree/diploma	3 (60%)

Results

Among the 15 athletes, only 13 completed this qualitative study, while out of the seven corresponding coaches, only four participated. Socio-demographic data for the 13 athletes and 4 coaches who completed the study are presented in Tables 1 and 2.

The athletes had a mean age of 23.4 ± 2.8 years, with a gender distribution of 8 males and 5 females. The coaches had a mean age of 50.4 ± 6.41 years, all of whom were male. In terms of education, 38% of the athletes had completed school education Level I (10 years of schooling), while 46% had completed school Level II (13 years of schooling). 16% of the athletes had enrolled in or completed a degree or diploma program. Athletes had a mean sports experience of 7.15 ± 3.60 years. Regarding performance levels, 38% of the athletes were classified as elite, while 62% were categorized as highly trained. These classifications were based on established criteria, such as those outlined by McKay et al. [23], which assess athletes' performance levels in relation to specific benchmarks. Participants represented four track and field categories: one sprinter, seven middle-distance runners, three long-distance runners, and two jumpers. The coaches had a mean service experience of 25.8 ± 6.76 years.

The findings of this study are organized into three major themes that emerged from the analysis, which provide insight into the various challenges and barriers faced by athletes and coaches, as well as the recommendations for improving the personalized sports nutrition intervention. The three overarching themes identified are: intrinsic factors related to challenges faced by athletes, extrinsic factors related to challenges faced by athletes, and recommendations to improve the efficiency of the sports nutrition intervention. Each of these themes is further subdivided into specific sub-themes, which offer a more detailed understanding of the experiences, challenges, and suggestions shared by the participants.

Theme 1: Intrinsic factors related to challenges faced by athletes

These refer to internal challenges faced by athletes, rooted in their personal circumstances and preferences, which they struggled with during the implementation of their nutritional practices [24].

Sub-theme I: knowledge gaps and challenges in implementing nutrition advice

Many participants struggled to comprehend and implement the prescribed dietary strategies, which were new and complex for them. This difficulty was evident in comments such as: "It was difficult to understand how to load creatine." (Sprinter, M, 22 years).

This suggests that the instructions provided were not sufficiently clear for some athletes. One participant mentioned: "After I mentioned my confusion, the doctor repeated everything. The first explanation was unclear." (Marathon runner, F, 22 years).

These challenges highlight a gap in understanding among athletes and the need for the intervention to communicate and address key dietary practices, particularly in areas such as supplementation, food choices, and timing more effectively. Athletes may require simplified, clearer instructions to help them successfully integrate dietary recommendations into their routines.

Coaches also observed challenges among athletes, particularly regarding their ability to grasp and follow nutritional advice. One coach noted:

"He's a bit scattered and doesn't really understand the things we tell him. He makes mistakes." (Coach 1, M, 59 years).

This highlights the additional challenge of ensuring athletes not only understand but can consistently apply nutritional guidance. Clear communication from both medical professionals and coaches is essential to help

athletes overcome the barriers they face in comprehending and applying the nutritional advice, which improves adherence to the intervention.

Athletes faced significant challenges in adapting their eating habits to align with dietary recommendations, often due to conflicts with their personal taste preferences. These difficulties were especially evident when athletes were asked to include foods they were not accustomed to or did not enjoy. Several participants expressed frustration with having to adjust their diets, highlighting how such changes impacted their overall experience.

For some athletes, the dietary shifts were so challenging that they had to make significant adjustments to meals they had long enjoyed. A middle-distance runner reflected, *"Sometimes I used to have kottu and fried rice for dinner, but I've to cut down on it as the doctor told me so. They were my favourite dinners. I also don't like chickpeas or black-eyed peas (cowpea)."*

Another athlete explained how they were told to incorporate foods they found unpalatable: *"I don't like mushrooms, but I ate them anyway."* The resistance to unfamiliar foods highlights not only emotional and psychological hurdles but also cultural and habitual factors that athletes face when trying to maintain a nutrition plan that doesn't align with their traditional tastes and dietary practices.

Sub-theme II: taste preferences

Some athletes reported that the foods recommended by their coaches and doctors often clashed with their established preferences. A marathon runner shared, *"The doctor recommended consuming olive oil, but I don't like the taste of it."* This dislike for certain recommended foods was a common challenge, as athletes were frequently asked to incorporate foods that were either unfamiliar or unappealing to them. Another marathon runner mentioned, *"The doctor advised me not to eat some of my favourite foods, like short eats (small, savoury snacks often eaten between meals) and murukku (crispy, deep-fried snacks), because they are high in fat. I also don't like foods like dhal and chickpeas, and I had to eat certain rice varieties I'm not fond of".*

These challenges, particularly regarding taste preferences, made it more difficult for athletes to adhere to the dietary recommendations. Some athletes also faced logistical issues that compounded this difficulty. For example, one marathon runner noted, *"Sir suggested having a packet of milk around 11 a.m., but since I don't like milk, I couldn't follow that. He also recommended eating chickpeas and sweet potatoes after training, but I don't like those either, and I don't have enough time to boil them."* These struggles with taste preferences underline a significant barrier to the implementation of prescribed dietary strategies. While the intervention provided personalized nutritional guidance, it is evident that an even more tailored approach, considering an athlete's individual cultural, social, and taste preferences, could improve adherence. Fostering a dialogue between athletes and nutrition experts about how to make dietary recommendations more appealing and feasible would also help athletes overcome these challenges more effectively.

Theme II: extrinsic factors related to challenges faced by athletes

Our qualitative analysis revealed several external challenges that athletes faced in adhering to the prescribed personalized SNI. These findings were grouped into two sub-themes: residential limitations Fig.1 [24], and practical difficulties, which highlight the constraints imposed by the environment and logistical factors.

Sub-theme I: residential limitations

The environmental and logistical challenges faced by athletes, particularly those living in camps or shared accommodations, created significant barriers to adhering to prescribed dietary guidelines. Many athletes reported the inability to prepare meals in accordance with recommended nutrition due to limitations in their living conditions.

One marathon runner explained, *"We don't get to cook our meals at the c we just have to eat whatever they give us. And even though the doctor advised against it, we still get coconut sambal every breakfast."* This highlights the lack of control over meal preparation and the difficulty in following dietary advice when forced to rely on available options that may not align with nutritional recommendations.

Similarly, a middle-distance runner shared concerns about the quality of food available at the boarding house: *"The problem is that I'm staying in a boarding place. Even though I want to eat like this, I'm not sure if the food available in the shops is okay. If I were at home, I'd just ask my mother not to add fat or oil."* This comment underscores the challenges athletes face when they are unable to oversee meal preparation, which prevents them from making healthier, more informed choices.

For athletes in camps, the limited food options further compounded the issue. Another marathon runner noted, *"When I was at the camp, it was difficult to follow the diet because we had to eat whatever they gave us. Rice was the main option, and it was hard to go out. I ended up eating at the canteen, where they mostly had kottu."* The reliance on a fixed menu in the camp, with limited variety and options, made it especially difficult to adhere to specific dietary needs and avoid foods that may not be conducive to optimal performance.

Coaches also observed the difficulties in maintaining a healthy diet when athletes were restricted to external

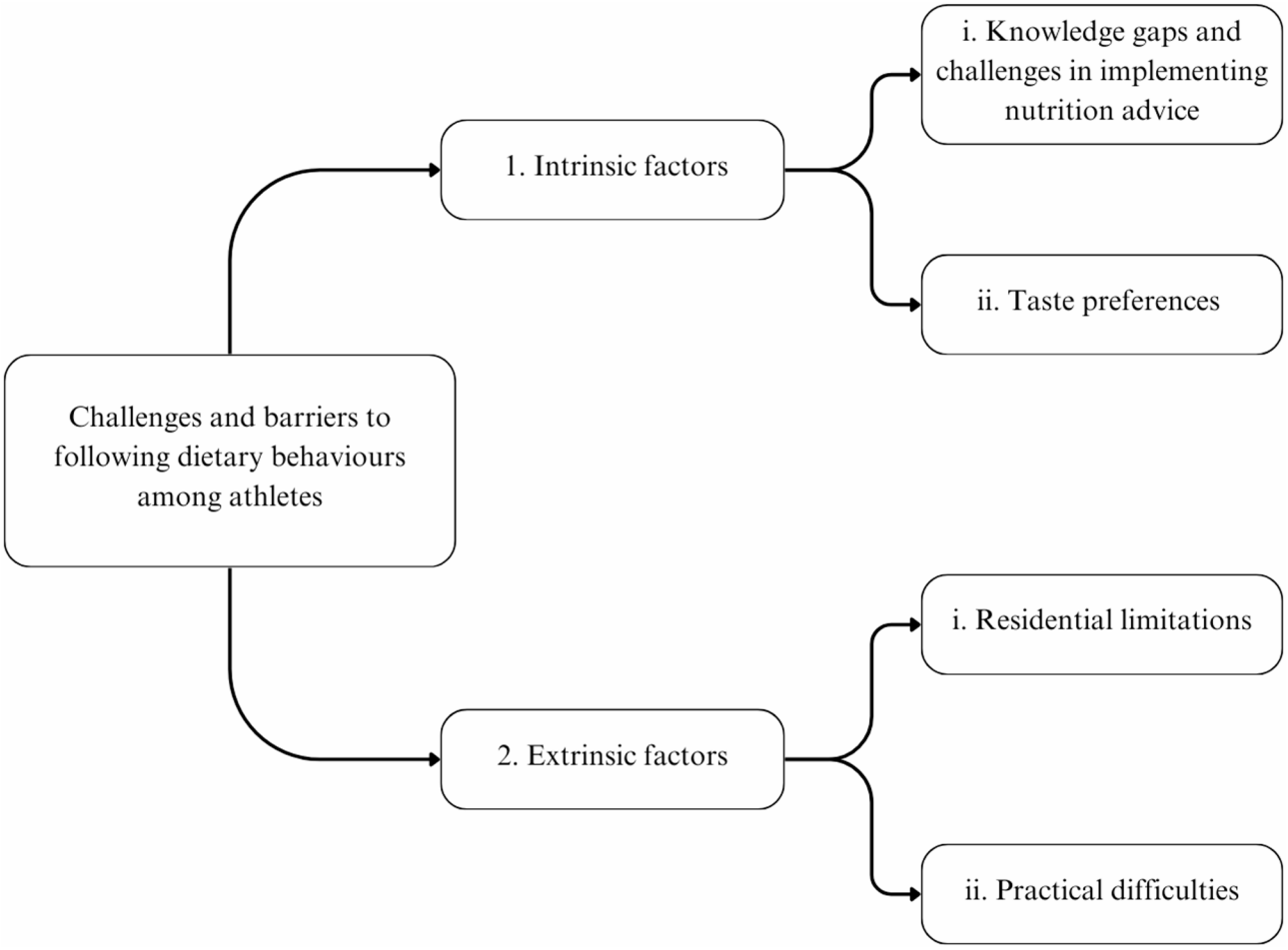

Fig. 1 Challenges and barriers to following dietary behaviours among athletes according to the point of view of athletes and coaches

food sources. One coach explained, *"Two of them are going to university, and the biggest issue I see is that they eat lunch from the canteen."* This illustrates how athletes' environments, particularly when they are away from home, can dictate their food choices, often leading them to consume meals that may not meet the necessary nutritional standards.

These environmental and logistical constraints emphasize the importance of considering living conditions when developing nutrition plans for athletes. Without control over meal preparation or access to proper food options, athletes may struggle to maintain their health and performance, highlighting the need for tailored support that takes their living and training environments into account.

Sub-theme II: practical difficulties

Practical difficulties emerged as a significant barrier for athletes in adhering to the prescribed nutritional strategies. These challenges were mainly linked to the demands of training, time constraints due to academic schedules, logistical issues like transportation, and the difficulty in sourcing specific foods. One marathon runner highlighted that the camp setting made it difficult to meet nutritional needs, saying, "*Sometimes I stayed at the camp and couldn't meet needs.*" Athletes balancing intense training with university responsibilities also expressed time management struggles, as exemplified by a jumper who stated, *"I couldn't make vegetable salads as the doctor recommended, as I go to university, I couldn't manage time for cooking."* These practical issues, alongside transportation and the time required to access meals, significantly hindered their ability to adhere to dietary recommendations.

In addition, athletes living in rural areas faced further challenges in sourcing specific foods as one sprinter mentioned, *"It was difficult to find village fruits like veralu and nelli,"* indicating difficulties with food availability in remote locations. Coaches recognized the mental stress caused by balancing academic commitments with athletic demands, with one coach commenting, *"Mental stress is high for them when they go to university because they have to balance assignments, exams, and training."*

The financial constraints faced by athletes in Sri Lanka, particularly amid the ongoing economic crisis, emerged as a significant barrier to adhering to prescribed nutritional strategies. The intervention recommended both whole foods and supplements as part of a personalized approach to optimizing athletic performance and recovery. However, it is important to note that while supplements such as protein powders, creatine, and olive oil were included as optional components of the dietary recommendations, the primary focus was on whole foods. These supplements were presented as supplementary strategies, and athletes were encouraged to prioritize accessible, culturally relevant food sources before considering supplementation.

The rising prices of essential items such as protein powders, creatine, and olive oil were particularly problematic. One middle-distance runner explained the difficulty in maintaining a supplementation routine due to financial strain, stating, *"Taking supplements was financially difficult for me"* (Middle-distance runner, M, 25 years). Another shared the challenges of purchasing specific items, saying, *"It's difficult to buy ISO 100 whey protein every time. I didn't receive a salary,"* which highlights the struggle when athletes rely on personal income to cover nutrition costs.

The intervention's focus on supplements was intentionally designed to enhance the nutritional strategies for athletes who had the financial capacity to afford them. However, the program also emphasized the flexibility in tailoring the nutrition plan to meet individual circumstances, ensuring athletes could still benefit from nutritional guidance even in the absence of supplements.

The increasing costs of products further strained athletes' budgets. A sprinter noted, *"Earlier, the prices were lower, so I could buy protein for around 13,000 LKR for one and a half months. But now, it's around 25,000 LKR."* These significant price increases left athletes feeling unable to maintain a consistent supplementation routine.

In the context of financial barriers, athletes highlighted the tension between their aspirations and the reality of adhering to the prescribed nutritional guidelines. One athlete emphasized the challenges they faced in trying to implement the advice despite the importance of proper nutrition for their athletic success: *"As professional athletes, if we want to make it to the Olympics, we should eat as the doctor said. However, when it comes to putting it into practice, we face these financial challenges."* (Sprinter, M, 25 years). This quote underscores the significant financial obstacles that can hinder athletes from fully adhering to personalized nutrition interventions, despite their awareness of the importance of proper nutrition for peak performance.

In addition to supplements, the cost of other recommended foods posed financial challenges. For example, one middle-distance runner opted for a cheaper alternative, saying, *"Extra virgin olive oil was very pricey, so I bought sunflower oil instead."* The cost of other essential foods also exceeded expectations, with one marathon runner remarking, *"The foods the doctor recommended were more expensive than I thought."*

The struggle to afford necessary nutrition often had broader implications, with some athletes unable to prioritize dietary needs due to other financial responsibilities. One marathon runner shared, *"We usually can't spend our entire salary on food as the doctor said,"* emphasizing the difficult balance between meeting basic living expenses and adhering to nutritional recommendations. Another sprinter revealed, *"Buying creatine from my salary was difficult. And it's finished now,"* illustrating how financial limitations could cut off access to supplements crucial for athletic performance.

Family financial responsibilities added another layer of complexity for some athletes. A coach provided insight into the realities faced by an athlete in the Air Force, stating, *"She joined the Air Force because her father can't afford everything. That family has three daughters including her."* This reflects how athletes, particularly those from families with multiple dependents, often had to seek additional sources of income to make ends meet.

These financial constraints underscore the broader issue of economic inequality in sports, where many athletes are unable to access the resources, they need to perform at their best. Without adequate financial support, both in terms of direct income and access to affordable nutritional resources, athletes may struggle to reach their potential, which could impact their long-term health and performance. Addressing these financial barriers is crucial to ensuring that all athletes, regardless of their economic background, have equal access to the tools and resources required for success.

Theme III: Recommendations and insights to improve the efficiency of sports nutrition intervention by athletes and coaches

This study aimed to gather recommendations and insights from athletes and coaches regarding the SNI to enhance its effectiveness in the future. Through this analysis, we identified four key sub-themes that provide critical feedback for refining the intervention. These subthemes include preferred study methods, which focus on the format and type of study materials; enhanced medical support, which emphasizes the need for more frequent consultations with the nutritionist; investing in young athletes, which highlights the importance of initiating such programs at the school level; and methodological enhancements, which outline additional suggestions to improve the delivery and overall impact of the intervention. These sub-themes collectively respond

to the research question, aiming to identify strategies for improving the sports nutrition intervention by aligning it better with athletes' and coaches' needs.

Sub-theme I: preferred study methods

The intervention provided participants with a sports nutrition guideline in the form of an e-book, distributed via WhatsApp. However, these insights revealed diverse preferences among participants regarding the format of the study material. While some athletes favoured the e-book format, others expressed a preference for printed versions of the guideline.

A marathon runner stated, *"I live in Haputale, so I can't carry books everywhere. It's better to have PDFs on my phone."* Similarly, a middle-distance runner mentioned, *"I prefer PDFs on my phone because other athletes might laugh if they see me reading a book."* These comments highlight their preference for digital materials, influenced by practical considerations and social dynamics. Factors such as educational background and social perceptions appear to shape their preferences.

On the other hand, many athletes expressed a clear preference for printed materials. A jumper explained, *"It's better to provide it as a book since we don't use WhatsApp much."* Another middle-distance runner added, *"Some people get headaches from looking at screens, especially when PDFs have small text."* These remarks underscore the potential limitations of electronic reading formats.

Athletes often mentioned time constraints and the practicality of accessing materials on the go. A marathon runner stated, *"If it were given as a book, I could even read it on the bus."* This comment reflects how athletes manage their time and incorporate learning into their routines. Furthermore, concerns about data loss were raised, as highlighted by a sprinter who said, *"It would be better to receive it as a book because PDFs can get deleted easily."*

In addition to preferences for either e-books or printed materials, some participants suggested alternative approaches. A sprinter proposed, *"If you teach this face-to-face, starting from the basics of sports nutrition, it will be more effective. I don't think everyone reads what you've sent."* This perspective underscores the potential value of interactive, direct teaching methods over static materials, whether digital or printed.

The findings reveal that athletes have varied preferences for the format of study materials, influenced by practicality, social perceptions, and personal circumstances. While e-books were favoured for their accessibility and convenience, printed materials were appreciated for ease of use, reduced strain, and reliability. Additionally, the feedback highlighted the need for more interactive and engaging methods, such as face-to-face teaching, to ensure the effective delivery of sports nutrition knowledge.

Sub-theme II: enhanced medical support

During the intervention, athletes met with a doctor once a month to discuss and address diet- and nutrition-related concerns. Feedback from participants highlighted the need for more frequent meetings, emphasizing the importance of regular monitoring and guidance.

A middle-distance runner commented, *"We've only met Sir four times; it would be better if it could be extended,"* while another athlete added, *"It would be better if we had more sessions in between so that monitoring could happen more regularly."* These statements reflect a clear desire for increased interaction with the doctor to address ongoing concerns. Another sprinter remarked, *"It would be better if we could talk more with the doctor,"* highlighting the need for readily available expert support, particularly as many athletes were new to sports-specific nutrition and required additional assistance.

Coaches also provided valuable feedback on the need for enhanced medical support. One coach suggested, *"It would be better if there's more communication with the coach. As a coach, we have limited knowledge on nutrition, so if we had the chance to talk to the doctor, it would be helpful. We could share the children's problems with him directly."* Another coach mentioned, *"We learned a lot from this program. I even referred to the PDFs."* These insights underline the importance of involving coaches more actively in the process, as they interact closely with athletes and play a key role in implementing nutritional strategies. Improving their nutrition knowledge and creating opportunities for direct communication with medical professionals would enable them to better support the athletes and contribute to the intervention's success.

In summary, participants strongly recommended increasing the frequency of doctor-athlete interactions and fostering better communication between medical professionals and coaches. These improvements could enhance the overall effectiveness of the intervention by ensuring consistent monitoring, tailored advice, and collaborative support for athletes and their teams.

Sub-theme III: investing in young athletes

During discussions with athletes and coaches, the importance of focusing on school-level athletes emerged as a key suggestion. Participants highlighted that many Sri Lankan school athletes perform exceptionally well at junior levels but often fail to sustain their careers due to a lack of guidance and exposure to negative influences.

One coach explained, *"If a program like this could be implemented for junior athletes, Sri Lanka could produce more talents. Many of these juniors get involved in bad habits due to a lack of support."* He emphasized the need for structured monthly monitoring and proper nutritional advice, adding, *"I truly believe we could even aim for the Olympics with consistent guidance and*

monitoring." Another coach shared similar views, noting, *"Many junior-level athletes are very talented and participate in junior athletic tournaments, but very few make it to the Olympics."* This highlights a missed opportunity to nurture and support emerging talent.

Additionally, affordability was identified as a significant barrier for school-level athletes. A sprinter pointed out, *"For school-level athletes, it's really hard to afford this kind of diet. It would be great if you could find sponsorships through your research to help with this."*

These insights underscore the untapped potential of school-level athletes in Sri Lanka and the pressing need to develop tailored interventions that provide education, resources, and sustained monitoring to foster their long-term success in sports.

Sub-theme IV: methodological enhancements

In addition to the key themes discussed earlier, athletes and coaches highlighted several methodological improvements to enhance the intervention's effectiveness.

One sprinter emphasized the value of incorporating sports-specific metrics to measure intervention outcomes more effectively, stating, "*It's better to focus on sports-specific metrics like squats, vertical jump height, and 1RM, both before and after the intervention. Since my body fat percentage has dropped, I'm expecting improvements in agility, power, strength, and overall performance. Every sport has its tests, and by analyzing these, we can make the training more effective.*" This suggestion highlights the importance of tailoring assessments to individual sports to better evaluate performance improvements, despite the added complexity.

Additionally, the practicality of daily documentation emerged as an area for improvement. A middle-distance runner suggested introducing an online platform, stating, "*When writing daily routines, it would be better to introduce an online form to fill them out instead of writing them down.*" This comment reflects the time constraints athletes' face and highlights the potential of digital tools to simplify data collection and monitoring.

These insights demonstrate the importance of refining the intervention's methodology to ensure it is effective, practical, and aligned with the specific needs of the athletes and their respective sports.

Discussion

To the best of our knowledge, this is the first qualitative study conducted with the aim of exploring the perceptions and experiences of athletes and coaches regarding personalized SNIs in a resource-limited environment. The findings highlight the challenges and barriers athletes face when trying to adhere to dietary recommendations, including financial limitations, taste preferences, and environmental constraints. These findings align with previous studies that have identified economic barriers as a key determinant of dietary adherence in low-resource settings [11]. Moreover, our study extends this understanding by emphasizing the psychological and cultural factors that further complicate adherence. The role of cultural and social influences on dietary habits has been extensively discussed in the literature, with studies indicating that food choices are deeply embedded within social norms, traditions, and personal identity [25]. The reluctance to adopt new dietary practices, even when scientifically supported, is often linked to cultural perceptions of food, the influence of family and peer networks, and the societal expectations placed on athletes [26]. By integrating these perspectives into our findings, this study contributes to a broader discourse on how social and cultural factors shape nutritional behaviours in sports settings.

This research provides valuable insights into the real-world applicability of personalized nutrition strategies in resource-limited settings. The results underscore the need for a multifaceted approach that incorporates the perspectives of athletes, coaches, and sports organizations, and emphasizes the importance of addressing individual and structural challenges. Addressing these barriers will require collaboration among stakeholders at multiple levels—athletes, coaches, institutions, and policymakers—to ensure the effective implementation and sustainability of personalized nutrition interventions.

Our observation that athletes often aspire to peak performance through personalized nutrition strategies, but face numerous, deeply ingrained barriers in implementing these recommendations, emerged as a key finding from this research. This study highlights the complex interplay of intrinsic and extrinsic factors shaping adherence to dietary interventions, as well as the broader implications for athletes' health, performance, and well-being.

The multifaceted nature of barriers

The findings reveal that financial constraints, knowledge gaps, and cultural resistance are deeply interconnected, creating a cascade of challenges for athletes. While previous research underscores the critical role of nutrition in optimizing athletic performance [27], our study offers a more nuanced understanding of the obstacles athletes encounter in real-world settings. For instance, the tension between the affordability and accessibility of prescribed foods highlights systemic inequalities in sports nutrition access, particularly in resource-limited settings such as Sri Lanka, which is currently classified as a bankrupt country facing significant economic instability [28]. As one participant remarked, *"Buying creatine from my salary was difficult,"* underscoring how economic barriers persist despite awareness of nutritional benefits. This

observation is consistent with prior research indicating that financial strain significantly reduces athletes' ability to follow evidence-based nutritional recommendations [29].

Beyond financial concerns, the emotional and psychological toll of dietary adjustments cannot be overlooked. Athletes often grapple with a conflict between adhering to unfamiliar dietary regimens and maintaining a sense of cultural and personal identity. This aligns with broader research suggesting that sustainable dietary interventions must account for individual preferences and cultural contexts to ensure long-term adherence [30, 31]. In many traditional societies, food is not merely a source of nourishment but also a key element of cultural heritage and social interaction [32]. Athletes may face pressure from family and peers to adhere to conventional eating habits, making it difficult to adopt new dietary practices that deviate from these expectations [33]. This dynamic is particularly relevant in Sri Lanka, where meals are often communal, and changes in dietary patterns can be met with resistance from both immediate and extended social networks. Recognizing these cultural dynamics is essential in designing interventions that are both effective and socially acceptable.

The role of structural and social factors

The environmental challenges faced by athletes highlight significant gaps in institutional support. For example, athletes in shared accommodations or training camps lack control over their meals, a finding consistent with studies on the structural limitations of institutionalized sports systems [34]. Coaches and support staff, while pivotal in shaping athletes' behaviours, may inadvertently reinforce these barriers by failing to provide comprehensive guidance or resources.

This interplay of individual, social, and institutional factors is analogous to the concept of "ecological resilience" in sports psychology, where an athlete's capacity to overcome adversity is influenced by both internal traits and external environments [35]. Our study adds to this literature by emphasizing the role of systemic constraints in limiting athletes' ability to adopt evidence-based nutritional practices, a perspective that has been underexplored in prior research. The sociological concept of "habitus" is particularly relevant here, as it suggests that athletes' behaviours and perceptions are shaped by ingrained social structures and cultural conditioning [36]. These subconscious influences can lead to resistance against dietary modifications, even when such changes are in their best interest. By framing nutritional adherence within this theoretical context, our findings highlight the need for interventions that go beyond individual education and address the broader social ecosystem that influences athletes' decision-making processes. For example, collaborating with catering services at training camps to provide meals that align with athletes' dietary advice could help create a supportive environment.

Reframing the narrative: from barriers to opportunities

While much of the focus has been on the challenges, our findings also highlight opportunities for transformative change. The involvement of coaches and nutritionists in bridging the knowledge gap is a key starting point. However, broader systemic changes—such as improving access to affordable, athlete-friendly foods and fostering a supportive dietary culture—are essential. This supports existing calls for holistic interventions that prioritize both the physical and psychological well-being of athletes [33].

Moreover, the findings challenge the notion that adherence to nutritional recommendations is solely an individual responsibility. Instead, they call for a paradigm shift toward a shared responsibility among athletes, coaches, sports organizations, and policymakers. As one coach insightfully observed, *"It's not just about the athlete; it's about the whole system." It's not just about the athlete; it's about the whole system."* This view aligns with sociocultural theories of health behaviour change, which argue that long-term adherence to dietary interventions is more likely when individuals are embedded in a supportive environment that normalizes and reinforces positive behaviours. By leveraging this perspective, sports nutrition programs can transition from isolated interventions to sustainable cultural shifts within athletic communities [37].

Insights for improvement: enhancing the effectiveness of SNI

Building on the identified barriers, several insights were provided to improve the effectiveness of SNI in the future. A key recommendation was to increase the frequency of consultations with nutrition experts. Athletes expressed the need for regular check-ins and more frequent interactions with doctors and nutritionists to ensure continuous monitoring and guidance. Additionally, the preference for more interactive and engaging methods of education, such as face-to-face teaching or practical demonstrations, emerged as an important insight. While digital resources such as e-books were seen as convenient, printed materials and in-person sessions were recommended to ensure broader accessibility and reduce technological limitations.

Investing in young athletes, particularly at the school level, was also emphasized. Many participants highlighted that talented junior athletes often fail to reach their full potential due to a lack of proper guidance and support. The recommendation to implement SNI at the school level, coupled with affordable nutrition programs,

could help nurture the next generation of athletes and prevent them from falling into negative habits due to a lack of proper training and nutritional guidance. This further underscores the importance of early intervention in shaping dietary habits, as younger athletes are more adaptable to behavior change and can integrate these practices into their long-term athletic development.

Strengths and limitations

This study offers valuable insights into athletes' and coaches' perceptions of a personalized SNI, highlighting the unique challenges faced in its implementation. By adopting a qualitative approach, we were able to capture the nuanced experiences of athletes and their coaches, providing a depth of understanding that quantitative methods alone could not achieve. The rich firsthand accounts from a diverse group of participants allowed for an exploration of complex themes such as knowledge gaps, taste preferences, financial constraints, and logistical difficulties, all of which are critical to improving nutrition strategies for athletes.

One of the key strengths of this study lies in its real-world relevance. The findings directly reflect the lived experiences of athletes, offering actionable insights for nutritionists, coaches, and sports organizations. Additionally, the inclusion of both athletes and their coaches as participants provided a holistic view of the intervention's impact, highlighting not only individual struggles but also the broader systemic issues that influence nutritional adherence. The detailed participant quotes further enrich the narrative, making the findings relatable and grounded in authentic experiences.

However, as with any study, there are limitations; while the depth of the qualitative data is a strength, it may not fully capture the broader experiences of all athletes across different sports or regions. Given the qualitative nature of the study, generalizability is not the primary goal, as qualitative research aims to provide depth and context rather than statistical generalization. Additionally, the reliance on self-reported data may introduce bias, as participants may have over- or under-reported their experiences due to social desirability or memory recall issues. Despite these limitations, the study provides a valuable starting point for further research into personalized nutrition interventions and their practical implementation in athletic contexts.

Recommendations for future research and practical application

This research provides valuable insights into the challenges and opportunities associated with implementing personalized SNI in resource-limited settings. To further enhance our understanding, future studies should incorporate larger and more diverse athlete populations across different regions and sporting disciplines. Additionally, exploring the longitudinal outcomes of SNIs—particularly their impact on long-term performance and athlete well-being—will provide deeper insights into their sustained effectiveness. A key area for further investigation is the development and evaluation of various communication strategies for delivering nutritional advice. Personalized nutrition strategies must be conveyed in a way that ensures accessibility, comprehension, and adherence. Investigating different formats—such as interactive education sessions, digital platforms, and traditional printed resources—will help determine the most effective methods for knowledge dissemination. Given that many athletes preferred printed materials, ensuring that sports nutrition guidelines are available in Sinhala, Tamil, and English in a clear and simplified manner is crucial. Providing e-books in athletes' native languages can further enhance accessibility, supporting more effective engagement with the guidance provided.

Beyond research implications, the findings hold significant practical relevance for enhancing nutrition practices specifically within the Sri Lankan track and field system. Sports organizations and governing bodies in Sri Lanka should prioritize structured educational programs that empower athletes to make informed dietary choices. These programs must move beyond basic awareness and provide actionable strategies tailored to athletes' financial and cultural realities. Moreover, targeted subsidies or sponsorships for sports supplements and specialized foods could play a pivotal role in ensuring that economic constraints do not hinder optimal nutrition.

Importantly, integrating cultural preferences and personal dietary habits into nutrition planning can enhance adherence and athlete satisfaction. Nutritionists and coaches should work closely with athletes to develop individualized meal plans that align with their cultural background while maintaining nutritional efficacy. This approach not only promotes better compliance but also fosters a sense of ownership and trust in the intervention.

Finally, to ensure the long-term success of SNIs, future research should adopt a systems-oriented approach, engaging key stakeholders—including policymakers, sports organizations, and healthcare professionals—to identify and address systemic barriers to effective implementation. Qualitative studies capturing the perspectives of these stakeholders will provide a more holistic understanding of the enablers and obstacles within existing sports nutrition frameworks. By shifting from an athlete-centric approach to a broader, systemic model, we can create a more supportive environment that empowers athletes to optimize both their performance and overall well-being.

Conclusions

Personalized nutrition interventions hold immense potential for optimizing athletic performance, but their success hinges on addressing the multifaceted barriers athletes face. By shifting from an individual-centric model to a systems-oriented approach, we can create a more inclusive and supportive environment that empowers athletes to achieve their full potential. In doing so, we not only enhance performance but also contribute to the broader goal of improving athletes' overall quality of life.

Abbreviations

1RM	One Repetition Maximum
CG	Control Group
EVOO	Extra Virgin Olive Oil
g/kg	Grams per Kilogram
IG	Intervention Group
IOC	International Olympic Committee
IU	International Units
ORS	Oral: Rehydration Solution
PB	Personal Best
RCT	Randomized Controlled Trial
SB	Seasonal Best
SNK	Sports Nutrition Knowledge
SNI	Sports Nutrition Interventions
SNKQ	Sports Nutrition Knowledge Questionnaire
USG	Urine Specific Gravity

Supplementary Information

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Supplementary Material 1

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Author contributions

KW conceived and designed the study. KW, RJ and RP contributed to drafting the manuscript. RJ and APH, as supervisory team members, participated in the revision of the paper. All authors provided valuable feedback on the manuscript. Additionally, all authors carefully reviewed and approved the final version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Human ethics and consent to participate declarations

This study was approved by the Ethics Review Committee, Faculty of Medicine, University of Peradeniya, Sri Lanka (Approval code: 2024/EC/21; Date: 2025/09/15). All experimental procedures were conducted following the Declaration of Helsinki. Informed consent was obtained from all participants before participation in the study.

Consent for publication

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Competing interests

The authors declare no competing interests.

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