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Therapeutic nutrition in endocrine and metabolic disorders: A focus on thyroid dysfunction

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Abstract
Thyroid disorders represent one of the most common endocrine abnormalities worldwide, affecting metabolic homeostasis, growth, and overall health. Nutritional interventions play a vital role in both the prevention and management of thyroid dysfunction, particularly hypothyroidism and hyperthyroidism. This review explores the role of therapeutic nutrition in endocrine and metabolic disorders, with a particular focus on dietary strategies that influence thyroid function. The paper discusses macronutrient and micronutrient requirements, the role of iodine, selenium, zinc, iron, and other trace elements, and the impact of dietary patterns such as gluten-free and plant-based diets. Emerging evidence on functional foods, probiotics, and nutraceuticals in thyroid health is also addressed.

Keywords: Thyroid, diet, human health, metabolic homeostasis, nutrition, foods, gluten-free diets

Introduction

The thyroid gland plays a central role in regulating metabolic processes through the synthesis and secretion of thyroid hormones, primarily thyroxine (T4) and triiodothyronine (T3) (Mullur, Liu, & Brent, 2014) [15]. Thyroid dysfunction, including hypothyroidism, hyperthyroidism, and autoimmune thyroid diseases such as Hashimoto's thyroiditis and Graves' disease, significantly impacts metabolic health. Nutritional status is a critical factor influencing thyroid function, as several nutrients are required for thyroid hormone synthesis, metabolism, and action (Chaker *et al*., 2017) [5].

The human endocrine system plays a pivotal role in maintaining homeostasis through the regulation of hormones, which are chemical messengers that influence nearly every physiological process. Among the various endocrine organs, the thyroid gland is one of the most vital, as it regulates metabolism, growth, energy balance, and thermogenesis. Thyroid dysfunction, which includes conditions such as hypothyroidism, hyperthyroidism, goiter, and autoimmune thyroid diseases like Hashimoto's thyroiditis and Graves' disease, represents a major global health concern with both clinical and subclinical presentations. According to the World Health Organization (WHO), thyroid disorders affect approximately 750 million people worldwide, with a significant proportion of cases going undiagnosed, especially in developing nations. The interplay between nutrition and thyroid health has been extensively documented, underscoring the critical role of therapeutic nutrition in both prevention and management of thyroid-related metabolic disorders (Zimmermann & Boelaert, 2015) [31].

Therapeutic nutrition, broadly defined, refers to the application of diet and specific nutrient interventions to prevent, manage, or alleviate disease states. In the context of endocrine and metabolic disorders, therapeutic nutrition seeks to optimize hormonal balance, reduce metabolic complications, and enhance overall quality of life. Since the thyroid gland is particularly sensitive to nutrient availability, including iodine, selenium, iron, zinc, and vitamin D, diet becomes an indispensable component of clinical management. Nutrient deficiencies or excesses can precipitate thyroid dysfunction, alter hormone synthesis, or exacerbate autoimmune activity, thereby complicating treatment outcomes. For instance, inadequate iodine intake remains the leading cause of preventable goiter and hypothyroidism globally, while selenium deficiency impairs the activity of selenoproteins involved in thyroid hormone metabolism (Zimmermann, 2016) [30]. Conversely, excessive iodine intake may trigger autoimmune thyroid disease in susceptible individuals, highlighting the delicate balance of nutritional modulation.

The significance of therapeutic nutrition in thyroid dysfunction is further emphasized by the close relationship between thyroid hormones and energy metabolism. Thyroxine (T4) and triiodothyronine (T3) regulate basal metabolic rate, carbohydrate metabolism, protein turnover, and lipid mobilization. Dysregulation of these hormones can lead to profound systemic effects. Hypothyroidism, characterized by insufficient production of thyroid hormones, is associated with weight gain, fatigue, cold intolerance, and dyslipidemia, while hyperthyroidism often results in weight loss, hyperphagia, heat intolerance, and muscle wasting. In both conditions, nutrition has a dual role: addressing the metabolic consequences and supporting pharmacological interventions. For example, dietary modifications aimed at controlling caloric intake, balancing macronutrients, and correcting micronutrient imbalances can improve symptom management and reduce comorbid risks such as cardiovascular disease and osteoporosis (Mullur, Liu, & Brent, 2014) [15].

Autoimmune thyroid diseases add another layer of complexity to nutritional management. Hashimoto's thyroiditis, the most common cause of hypothyroidism in iodine-sufficient regions, involves immune-mediated destruction of thyroid tissue. Nutritional factors such as gluten, selenium, vitamin D, and omega-3 fatty acids have been implicated in modulating immune responses in these patients. Similarly, Graves' disease, the leading cause of hyperthyroidism, may benefit from dietary interventions aimed at reducing inflammation, oxidative stress, and micronutrient deficiencies. The growing field of immunonutrition suggests that targeted dietary patterns, including anti-inflammatory diets, gluten-free protocols, or

the Mediterranean diet, may complement conventional therapy in autoimmune thyroid conditions (Pizzorno, 2019) [17].

Another critical aspect of therapeutic nutrition in thyroid dysfunction is its interaction with pharmacotherapy. Levothyroxine, the standard treatment for hypothyroidism, has well-documented interactions with dietary components such as calcium, iron, soy, and fibre, which can impair drug absorption if consumed concurrently. Similarly, in hyperthyroidism, anti-thyroid medications may increase susceptibility to oxidative stress and nutrient depletion, requiring compensatory dietary support. Therefore, therapeutic nutrition not only assists in managing the primary disease but also ensures optimal efficacy of pharmacological treatment, reducing the risk of iatrogenic complications.

From a public health perspective, the burden of thyroid dysfunction is considerable, with significant socioeconomic consequences. Iodine deficiency disorders (IDDs), for instance, remain prevalent in over 30 countries despite salt iodization programs. In India alone, it is estimated that nearly 200 million people are at risk of IDD, reflecting dietary inadequacies and disparities in food fortification programs (Kapil, 2010) [11]. Furthermore, the rising incidence of obesity, metabolic syndrome, and environmental toxin exposure has been associated with altered thyroid function, suggesting that modern lifestyle and dietary patterns may exacerbate endocrine disorders. Against this backdrop, therapeutic nutrition emerges not only as a clinical tool but also as a preventive strategy, advocating for dietary policies, awareness campaigns, and community-level interventions.

Recent advances in nutritional science have expanded the understanding of how diet interacts with thyroid physiology. For instance, the gut–thyroid axis, an emerging research focus, highlights the influence of gut microbiota on thyroid hormone metabolism, autoimmunity, and nutrient absorption. Dysbiosis has been linked to autoimmune thyroid disease, raising the possibility of probiotic and prebiotic interventions as part of therapeutic nutrition. Similarly, nutrigenomics provides insights into how genetic variations affect nutrient requirements and thyroid function, offering a path toward personalized dietary strategies. These developments underscore that therapeutic nutrition is not a static concept but a dynamic, evolving discipline informed by ongoing scientific discoveries (Virili *et al*., 2018) [25].

Moreover, therapeutic nutrition must be contextualized within the holistic framework of lifestyle management. Thyroid dysfunction often coexists with other metabolic disorders such as diabetes mellitus, dyslipidemia, and polycystic ovarian syndrome (PCOS) (Nair *et al*., 2024) [16]. Therefore, dietary interventions must be integrated with exercise, stress management, and sleep hygiene to optimize endocrine health (Ajingi *et al*., 2024) [1]. For example, in hypothyroid patients with obesity, a calorie-controlled, nutrient-dense diet combined with physical activity can improve weight management and cardiovascular outcomes (Di Vincenzo, 2006) [8]. In hyperthyroid patients, strategies to counteract muscle wasting and bone loss require both nutritional and lifestyle adjustments (Rodolfi *et al*., 2025) [20].

The importance of individualized nutrition cannot be overstated. While population-level interventions such as salt iodization address broad deficiencies, therapeutic nutrition for thyroid dysfunction requires tailoring to the patient's condition, comorbidities, medication use, and cultural dietary practices (Hoolihan, 2003) [10]. For instance, vegetarian populations relying heavily on goitrogenic foods such as cruciferous vegetables and soy may require specific dietary adjustments to prevent thyroid hormone disruption. Likewise, patients with malabsorption syndromes, celiac disease, or chronic illnesses may need specialized nutritional care. Hence, the integration of nutritional assessment into routine thyroid management is essential for comprehensive care.

Therapeutic nutrition occupies a central role in the prevention, management, and prognosis of thyroid dysfunction (Shulhai *et al*., 2024) [23]. It bridges the gap between medical treatment and lifestyle, providing patients with accessible, non-invasive, and sustainable strategies to improve health outcomes (Trovato, 2014) [24]. By focusing on nutrient adequacy, dietary patterns, drug–nutrient interactions, and immune modulation, therapeutic nutrition not only addresses the immediate symptoms of thyroid disorders but also mitigates long-term risks. Furthermore, the emergence of precision nutrition, gut microbiota research, and nutrigenomics promises a future where dietary interventions for thyroid dysfunction will be increasingly personalized, evidence-based, and effective (Pokushalov *et al*., 2024) [18].

This review on "Therapeutic Nutrition in Endocrine and Metabolic Disorders: A Focus on Thyroid Dysfunction" seeks to explore the multifaceted role of nutrition in thyroid health. It will examine the physiological basis of nutrient–thyroid interactions, evaluate the evidence for specific dietary strategies, and highlight emerging trends in nutritional therapeutics. By doing so, it aims to provide a comprehensive understanding of how therapeutic nutrition can be leveraged to improve clinical outcomes, enhance patient quality of life, and contribute to the broader goal of endocrine health promotion.

Overview of Thyroid Dysfunction

1. Hypothyroidism

Hypothyroidism is characterized by reduced thyroid hormone production, often due to iodine deficiency or autoimmune destruction of the gland. Symptoms include weight gain, fatigue, cold intolerance, and impaired cognitive function (Biondi & Cooper, 2019) [3].

2. yperthyroidism

Hyperthyroidism results from excessive thyroid hormone production, commonly associated with Graves' disease or toxic nodular goiter. Symptoms include weight loss, anxiety, tachycardia, and heat intolerance (Ross, 2016) [21].

3. Autoimmune Thyroid Disorders

Hashimoto's thyroiditis and Graves' disease represent autoimmune conditions where nutrition and immune-modulating diets may significantly influence disease progression (Antonelli, Ferrari, & Fallahi, 2015) [2].

Role of Nutrients in Thyroid Health

1. Iodine

Iodine is essential for thyroid hormone synthesis. Both deficiency and excess can cause thyroid dysfunction (Zimmermann & Boelaert, 2015) [31]. Therapeutic nutrition

emphasizes adequate but not excessive iodine intake, primarily from iodized salt, seafood, and dairy products.

2. Selenium
Selenium acts as a cofactor for deiodinases, enzymes responsible for converting T4 to active T3. Selenium supplementation has shown benefits in reducing thyroid peroxidase antibodies in autoimmune thyroiditis (Winther *et al*., 2020) [27].

3. Zinc
Zinc contributes to thyroid hormone metabolism and immune function. Deficiency has been associated with impaired T3 and T4 synthesis (de Benoist *et al*., 2008) [6].

4. Iron
Iron deficiency anemia impairs thyroid peroxidase activity, reducing thyroid hormone synthesis. Iron supplementation improves thyroid function in deficient individuals (Zimmermann, 2009) [29].

5. Vitamin D
Vitamin D deficiency is prevalent in autoimmune thyroid disorders. Adequate intake may modulate immune responses and reduce thyroid autoimmunity (Mackawy, Al-Ayed, & Al-Rashidi, 2013) [12].

6. Other Nutrients
B vitamins, particularly B12, are often low in hypothyroidism and should be monitored. Omega-3 fatty acids also play a role in reducing inflammation in autoimmune thyroid disease (Mazokopakis *et al*., 2010) [13].

Dietary Interventions
1. Gluten-Free Diet
In patients with Hashimoto's thyroiditis and celiac disease, a gluten-free diet has been shown to reduce antibody levels and improve thyroid function (Virili *et al*., 2018) [25].

2. Plant-Based Diets
Plant-based diets rich in antioxidants may support thyroid health, although caution is warranted with goitrogen-containing foods like cruciferous vegetables, which may impair iodine uptake if consumed excessively (Di Ciaula & Portincasa, 2017) [7].

3. Mediterranean Diet
The Mediterranean diet, rich in fruits, vegetables, fish, and olive oil, provides antioxidants and omega-3 fatty acids beneficial for autoimmune thyroid conditions (Widmer *et al*., 2015) [26].

4. Caloric and Macronutrient Balance
Energy balance is critical in hypothyroidism, where weight gain is common. Controlled carbohydrate intake can improve insulin sensitivity and metabolic outcomes in thyroid dysfunction (Bozkurt *et al*., 2012) [4].

Functional Foods and Nutraceuticals
1. Probiotics
Gut microbiota influences thyroid autoimmunity and hormone metabolism. Probiotics may improve gut-thyroid axis regulation (Zhao *et al*., 2018) [28].

2. Phytochemicals
Polyphenols, flavonoids, and curcumin exhibit antioxidant and anti-inflammatory effects that may benefit thyroid health (Fallahi *et al*., 2019) [9].

3. Herbal Therapies
Ashwagandha (Withania somnifera) has shown promising results in improving thyroid hormone levels in subclinical hypothyroidism (Sharma *et al*., 2018) [21].

Clinical Implications and Guidelines
Nutritional therapy should complement pharmacological treatment in thyroid disorders. Personalized nutrition based on biochemical parameters, dietary intake, and genetic predisposition is essential for optimizing outcomes (Redman *et al*., 2016) [19]. Multidisciplinary care involving endocrinologists, dietitians, and nutritionists is recommended.

Nutrients such as iodine, selenium, iron, zinc, and vitamin D are critically involved in thyroid physiology and immune modulation. Deficiencies or excesses of these nutrients can impair thyroid hormone synthesis, metabolism, and action (Zimmermann & Boelaert, 2015 [31]; Mullur *et al*., 2014) [15]. Table 1 summarizes the essential nutrients for thyroid health, their functions, and major dietary sources.

Table: 1 Nutrients and Their Role in Thyroid Health

Nutrient	Primary Function in Thyroid Health	Food Sources	Deficiency/Excess Consequences
Iodine	Essential for synthesis of T3 and T4 hormones	Iodized salt, seaweed, dairy, fish	Deficiency: Goiter, hypothyroidism; Excess: Autoimmune thyroiditis, hyperthyroidism
Selenium	Cofactor of selenoproteins (e.g., deiodinases) that convert T4 → T3; antioxidant defense	Brazil nuts, seafood, eggs, whole grains	Deficiency: Impaired hormone conversion, Hashimoto's risk; Excess: Toxicity, GI upset
Iron	Required for thyroid peroxidase (TPO) activity in hormone synthesis	Red meat, spinach, legumes, fortified cereals	Deficiency: Reduced TPO activity, hypothyroidism risk
Zinc	Regulates thyroid receptor function and hormone metabolism	Meat, shellfish, pumpkin seeds, nuts	Deficiency: Impaired T3 action, alopecia, growth retardation
Vitamin D	Modulates immune system, reduces thyroid autoimmunity	Sunlight exposure, fatty fish, fortified milk	Deficiency: Linked with Hashimoto's thyroiditis and Graves' disease
Vitamin A	Regulates thyroid hormone receptor expression and TSH secretion	Liver, dairy, leafy greens, carrots	Deficiency: Impaired hormone synthesis, increased TSH
Omega-3 fatty acids	Anti-inflammatory effect in autoimmune thyroid disease	Fatty fish, flaxseeds, chia seeds	Deficiency: Worsens inflammation in Hashimoto's, Graves'
B vitamins (B12, folate)	Support energy metabolism, homocysteine regulation	Meat, dairy, legumes, leafy greens	Deficiency: Fatigue, anemia, aggravated hypothyroid symptoms

Future Perspectives

Emerging research is focusing on nutrigenomics, gut microbiome interactions, and bioactive compounds in thyroid health. More randomized controlled trials are needed to establish evidence-based nutritional interventions for thyroid dysfunction.

Conclusion

Therapeutic nutrition plays a vital role in the management of thyroid dysfunction. Adequate intake of iodine, selenium, zinc, iron, vitamin D, and omega-3 fatty acids is critical for optimal thyroid function. Dietary approaches, including gluten-free, Mediterranean, and plant-based diets, along with functional foods, may provide additional benefits, especially in autoimmune thyroid disease. Future research should emphasize personalized and integrative nutrition strategies to improve clinical outcomes in thyroid disorders.

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