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REVIEW ARTICLE

Nutrition Therapy in Pediatric Burns

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Abstract: ***Background*:** Burns are defined as injuries resulting from exposure to thermal radiation, electrical or chemical exposure of the skin or organic tissues. It has high mortality and morbidity in low and middle-income countries.

***Objective/Method*:** The objective of this study is to evaluate the present knowledge principles of nutritional therapy for pediatric burns from the dietician's perspective, taking into account the epidemiology and physiology of the burn.

The purpose of burn treatment is to provide survival and tissue repair and to increase immunity. Therefore, besides fluid electrolyte replacement and surgical interventions, nutritional therapy is quite important. Nutrition principles should aim to reduce inflammation and meet hypermetabolic needs.

***Results*:** In the clinical practice of children suffering from burns, daily energy need is calculated by adding the recommended energy expenditure to the burn percentage, but the most accurate method is the use of indirect calorimetry. Protein requirement is around 1.5-3.0 g/kg/day. Carbohydrate intake should be 55-60% of total energy intake, while lipids should be less than 30%. Vitamin supplements in the form of a multivitamin are recommended in addition to vitamin A, vitamin C, and Zinc. In cases where oral intake is insufficient, enteral nutrition should be applied as soon as possible. When enteral feeding is contraindicated, parenteral nutrition is preferred.

***Conclusion*:** Evaluating the nutritional status of children and meeting macro and micronutrient needs accelerate wound healing, shorten hospital stay, and reduce mortality.

Keywords: Burn, nutrition therapy, pediatric burns, nutraceuticals, energy calculation, child nutrition.

1. INTRODUCTION

A burn is an injury of the skin or other organic tissue due to exposure to heat, thermal radiation, radioactivity, electricity, or chemicals. Although it is claimed that the history of the burn started with the discovery of the fire, it is estimated that people faced the problem of burns from the sun and hot springs. Although written documents regarding burn treatments are extant from the time of Hippocrates, burns were graded in the 17th century, and the view that cold application was effective in pain management was revived in the 18th century. Burn treatment in accordance with modern commentary began after World War II. Significant advances have been made in the treatment of burns with the modern burn centres that were established with improved technological developments [2, 3].

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Burns which result from preventable accidents mostly occur at home or in the workplace. Non-fatal burns prolong hospitalization, can cause disability, and can lead to stigmatization and rejection in society. Therefore it is important to show sensitivity to burn reasons for many reasons [2]. Burns can occur due to traffic accidents, poisoning, falling, and suffocation [4]. Children are in the risk group for reasons such as curiosity and inability to predict the consequences of dangers. In addition to these, child workers or children being employed in inappropriate household chores are also at increased risk [5]. Alcohol and cigarette substance addictions, attacks or injuries, the use of gas oil for heating purposes, and insufficient security measures can be listed among other risk factors [1]. In most of the studies conducted in burn centres in Turkey, it was reported that scalding burns, that is, burns due to contact with hot liquid, were more common [6].

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tional therapy is quite important. Nutrition principles should aim to reduce inflammation and meet hypermetabolic needs. The aim of this article is to determine how to plan nutritional therapy for pediatric burns from the dietician's perspective, taking into account the epidemiology and physiology of the burn.

1.1. Burn Epidemiology

According to the World Health Organization (WHO), it is estimated that 180,000 deaths in low and middle-income countries are caused by burns [7]. Two-thirds of the world's burns are seen in Africa and Southeast Asia. Every year 1 million people in India suffer from moderate to severe burns. According to the WHO, children under 5 years of age in Africa experience twice as many burn-related deaths compared to children at the same age in the rest of the world [1]. Insufficient medical care in certain regions also increases mortality and morbidity. Child burn deaths are seven times higher in low-income countries than in high-income countries. In Bangladesh, 173,000 cases of child burns are reported each year. It is estimated that 17% of children who suffer from burns in Colombia, Egypt, and Pakistan have a temporary disability and 18% experience a lifelong disability. It has been reported that burns are responsible for 5% of the incidence of disability in Nepal [1, 4].

1.2. The Severity of the Burn

The severity of a burn is determined by its depth, width, and tissue damage. Burns are classified as first, second, third, and fourth-degree burns according to their depth [2, 8]. In first degree burns, superficial parts of the epidermis are destroyed. Hyperaemia, erythema, and hyperthermia are observed in the skin. Within a week, the damaged epidermis is shed, and the recovery period is short. Sunburn is an example of a first-degree burn. In a second-degree burn, the epidermis is severely damaged, while the dermis remains in reasonably good condition. With the accumulation of protein-rich fluid under the dermis, blisters and oedema occur. This is painful and leave scars after healing. Second-degree burns such as scalds heal within 14-21 days. In a third-degree burn, all skin and subcutaneous tissue is damaged. Pain sensation disappears and many complications begin. In fourth-degree burns, muscles, tendons and bones, are damaged and considered to be a deep injuries that, require extensive surgical intervention, in which tissues undergo necrosis, and amputation is inevitable. Burns as the result of attacks and flames are two common examples of fourth-degree burns [2, 3, 7, 8].

The most common three methods used in classification according to the width of the burn are as follows: Palm (1%), Wallas rule (9's rule), or Lund Browder Card. The palm rule is a suitable method for adults, the area as much as the palm is calculated as 1%. The application of the Wallas rule for adults but not for children, where the calculation is made by adding the percentages corresponding to the age and the area of the burn on the Lund Browder card [6, 9-11]. In the Plam method rule, excluding the fingers, the palm of the patient's hand should be approximately 0,5% of the total burn surface area. The entire palm surface including fingers should be 1% percent in patients' burn widths. The Wallas rule, or rule of nines is an easy and fast method for adults. The head and each arm represent 9% of the body, each leg and the anterior-posterior trunk represents 18%, and the perineum is 1% of the total burn surface area. The application of the rule of nine for children is different. With children, the head, back, and chest are 18%, each arm 9%, two legs %27, and the perineum 1% of the total burn surface area. However, it is better to use the Lund Browder card, which defines the proportions of body parts according to age, and is prepared by taking the growth and development in children into consideration. According to this card, which has been updated in recent years, the proportions of body parts are shown by considering the infancy period, toddler period, school age period separately [6, 9-13].

1.3. Burn Pathophysiology

Burns cause tissue damage, loss of fluid and protein, and also cause hormonal, cardiac, respiratory, and immunological responses in the body. These responses vary according to the degree of the burn, its total surface area, and age of the patient [8, 9]. As a result of the local inflammatory response, vasodilation and increase in vascular permeability occur, and as the burn surface area expands, it causes a systemic inflammatory response [7]. After the burn, a hypermetabolic state develops due to fluid replacement therapy and increased oxygen demand. Body temperature increases, the levels of the stress hormones catecholamine, glucagon, and cortisol increase, while insulin and triiodothyronine (T3) values decrease. Protein catabolism increases with the increase of catecholamines, and lipolysis and gluconeogenesis are stimulated. While high glucose levels in the blood help to meet the increased energy level, the consumption of muscle proteins by gluconeogenesis is preserved [6, 10]. However, for patients who do not have sufficient glycogen storage to respond to trauma, short hyperglycaemic responses, or hypoglycaemic problems may occur [14, 15].

Excessive hyperglycaemia negatively affects wound infection and healing. Since insulin is an anabolic hormone, its use when necessary has been found effective. However, keeping the blood glucose level within an appropriate range helps to control the metabolic response [16-18]. Acute-phase proteins increase in the liver due to stress. Ensuring early nutrition provides regulation of the metabolic rate, blood sugar, liver functions and accelerates the healing process [6, 10].

A burn results in a loss of water due to evaporation with heat. Further, oedema occurs because of the leakage of plasma proteins from damaged vessels into the intercellular space. Hypovolemia occurs in patients with the escape of intracellular fluid outside the cell. Hence,fluid replacement therapy is important [3]. The first cardiovascular response is a decrease in cardiac output and an increase in systemic vascular resistance. When fluid loss is continuous and vascular volume decreases, cardiac blood pumping and blood pressure remain low for 18-36 hours after the burn. In the end, catecholamines are released from the sympathetic nervous system. In this process, when hypovolemia is improved by fluid replacement, the cardiac performance also improves. While the increased cardiac output increases the blood flow to the burned area, the purpose of metabolism is to provide oxygen and nutritional support. The gastrointestinal system and blood supply are impaired due to the decrease in cardiac output after the burn. Therefore, gastric mucosal integrity and motility are impaired. As a result of the stimulation of the sympathetic nervous system, the release of epinephrine and norepinephrine increases, and peristalsis of the gastrointestinal system decreases [11, 15].

In addition to all of these pathophysiological changes, there is a decrease in the immune response. Open wounds and reduced immune response create a very suitable environment for bacterial invasion. To ensure wound healing and to stop hypermetabolism in the burn, peeling, grafting, dressing, pain treatments, and other pharmacological treatments are performed [18]. Solving the problem of insomnia in pediatric patients and early enteral feeding also contribute to recovery. Whether the use of anabolic hormones such as testosterone, insulin to slow down hypermetabolism, or gene therapy can be used are still on the agenda [15, 18].

2. NUTRITION THERAPY

The primary goals in burn patients are survival, tissue repair, and enhancement of immunity. In an optimal nutritional treatment, it is important to ensure proper energy, protein-energy balance, oral nutrition if possible, and early feeding. Enteral nutrition can be used as a second choice. Unless necessary, parenteral nutrition should be avoided due to the risks of sepsis and thrombophlebitis [8, 9, 16].

Nutritional support in burn patients is needed to fulfill the increased caloric requirements caused by the hypermetabolic state while avoiding overfeeding [19]. However, it should be kept in mind that hypercaloric feeding may cause hyperglycemia, hepatic steatosis, deterioration in liver and kidney function tests, and can even cause alkalosis with excessive CO2 release and accumulation [2, 13]. Numerous formulas to estimate the caloric needs of burn patients have been developed and used over the years [20]. The most common method used to calculate energy need is the Curreri equation. While using this formula, it is appropriate to determine the target range using a few additional formulas and to re-evaluate according to the changed metabolic state [8]. The amount of energy required according to the Curreri formula is calculated by determing the daily recommended energy level and by multiplying the burnt surface area by the fixed coefficients determined by age (Table **1**). However the energy expenditure of the burnt patient may change over time and the energy requirement calculated with the formulas can be hypercaloric. For this reason, the use of indirect calorimetry is the most appropriate method for calculating the energy need of a burn patient.

2.1. Assessment of Nutritional Status

Despite variables such as body weight, oedema, amputation, and bulky clothing, these are still important criteria in the assessment of nutritional status. The fact that the bare weight of the patients is in the range of 90-110% of the body weight at which they first apply to the hospital is considered positive in the evaluation of the nutritional status. Indirect calorimetry is considered the gold standard in non-critical diseases, but it may be difficult to use in burn trauma patients due to amputation or loss from open wounds. When the respiratory coefficient is between 0.80-0.90, it is thought that the optimal macronutrient need is met [8, 15, 21].

In monitoring hepatic proteins, albumin, prealbumin, and C-reactive protein should be considered. Because albumin has a half-life of 20 days and is an acute phase reactant, it may be partly suggestive in the treatment phase, not in the acute phase. A prealbumin half-life of 2-3 days may be an appropriate parameter for the evaluation of nutrition, but it should be kept in mind that it is an indicator that can also be affected by inflammation. C-reactive protein levels are known to decrease with aggressive diets. Determining the nitrogen balance is important for monitoring anabolic processes. There is a formula for calculating the loss of nitrogen from the open wound in burn patients, but the use of the formula is not very effective because conditions such as wound closure processes and epithelization change the nitrogen balance. The standard nitrogen balance calculation formula (intake protein / 6.25- (urine urea nitrogen + 4)) can be used. Considering the losses from the open wound, between 5 and 10 g of nitrogen can be added to the calculation [8, 20, 22].

Many screening tests have been developed for the nutritional evaluation of pediatric patients. The most commonly used of these are the Pediatric Nutritional Risk Score (PNRS-France), the Subjective Global Nutritional Assessment (SGNA-Canada), the Screening Method for Determining Nutritional Status and Growth Risk (STRONGkids-Netherlands), the Pediatric Yorkhill Malnutrition Score

Table 1. Estimated Energy Calculation in Burn Patients [12, 19].

Equation	Age/Year	Estimated Energy Requirement/kcal
Curreri	<1	Recommended dietary allowance + 15 x (burned surface area)
	1-3	Recommended dietary allowance + 25 x (burned surface area)
	4-15	Recommended dietary allowance + 40 x (burned surface area)
	16-59	(25 x weight in kg) + 40 x (burned surface area)

(PYMS-England), and the Malnutrition Assessment Screening Method in Pediatrics (STAMP-England) [23-27]. It is important to monitor children who receive burn treatment with nutritional follow-up tests during their hospitalization and to monitor growth after discharge [16].

2.2. Nutritional Support

In cases where the energy consumed is less than the energy taken, nutritional support is planned for patients [21]. Enteral support is the primary choice due to its benefits in terms of digestion and absorption in the intestines. Oral intake is supported in cases with a burn percentage below 20%, and 24-48 hours are allowed to reach full calories [28]. Most experts would agree that nutrition should be started within the first three days of injury, preferably within the first 48 hours [29]. Enteral support is considered in burns with a body surface area of more than 20%, or in patients requiring ventilator support [8]. Enteral nutrition is performed by nasogastric, nasoduodenal route, or in cases where an indication is available, percutaneous endoscopic gastrostomy or jejunostomy [16]. The parenteral route is less desirous because of the risks of catheter-related infections and thrombophlebitis in burns. However, parenteral nutrition is used in cases where there occurs the inability to tolerate enteral feeding, severe diarrhoea, and gastrointestinal insufficiency [8, 30].

In the selection of enteral products, products containing high-quality protein, high carbohydrate, low fat, and low linoleic acid are preferred [14, 16]. Displacement of body fluid due to trauma also causes oedema and malabsorption disorders in the intestines. Peptide-based modular products are most commonly used to increase absorption. Depending on the progression of the disease, the target dose is reached in 12, 24, or 72 hours [21]. The fat content and composition of the products are important in the use of diabetic products in diabetes patients. In recent years, the benefits of intraoperative nutrition, as well as preoperative and postoperative nutrition, have come to the fore. It has been reported that intraoperative nutrition has positive effects on albumin deficit, wound healing, and oxygen balance when patients are potentially most prone to a calorie deficit [8, 30].

According to the results of a systematic meta-analysis study comparing the efficacy of early and late enteral nutrition therapy in the pediatric burn population, an approximate 3.7-day reduction in the hospital stay of children who received early enteral nutrition therapy was observed. In addition, an increase in the insulin/glucagon ratio was observed, which was considered positive for anabolic processes. Although there was an increase in the incidence of diarrhoea and vomiting as a result of early feeding, it was concluded that enteral nutrition may be more effective in the early period when necessary [31].

2.3. Macronutrients

In critically ill patients, energy from carbohydrates saves nitrogen, unlike fat. It is suggested that 55-60% of the energy should come from carbohydrates [8, 10, 21]. A serum glucose level in the range of 110-150 mg/dl is considered normal. Strict glucose monitoring decreases mortality and morbidity in pediatric burn patients. It must be kept in mind that excessive carbohydrate intake causes hyperglycaemia, dehydration, and respiratory problems [20].

Nitrogen is necessary for the full recovery of the skin losses caused by oedema and for wound healing. It is widely believed that 20-25% of the total energy taken comes from proteins. It has been reported that the amount of protein in the range of 1.5-3.0 g/kg/day in pediatric burn patients improves nitrogen balance, immunity, and survival [6, 7, 10, 20]. Studies have concluded that 20-23% protein intake of energy reduces the length of hospital stay in infants and children [8]. Protein intake is not evaluated independently of energy. High protein intake without adequate energy support is not recommended as it increases urea production rather than being used for anabolic purposes. The patient's fluid intake and discard and the monitoring of the serum urea-creatinine provide information about the patient's optimal protein needs [20, 21]. Catabolism is known to reduce plasma albumin levels with increased capillary permeability. It has been reported that albumin supplementation does not have the desired level of beneficial effect in children with severe burns [32].

In the past, fats have been seen as the main energy source for burn patients who need high energy, due to their high energy content. In addition to its positive effects such as providing myelinization, increasing the absorption of fat-soluble vitamins A, D, E, and K, the immunosuppressive effects of fats have been emphasized in recent years. With the increase of stress hormones like catecholamine and glucagon, glycerols are used for gluconeogenesis and can reduce insulin sensitivity. On the contrary, when lipolysis is triggered, free fatty acids increase oxidation. Thus, it is recommended that the energy coming from the fat does not exceed 30% of the total energy [8, 21]. Fats, unlike carbohydrates, neither trigger nitrogen retention nor the anabolic hormone insulin. Therefore, it is considered ideal if the carbohydrate content is high in the diet and the ratio of energy coming from fat is in the range of 20-25% [10, 21]. Due to the increase in prostaglandin synthesis in high-fat diets, there is a disruption in coagulation mechanisms and the need for gluconeogenesis to provide blood glucose. It is important to monitor patients in terms of hyperlipidaemia and hepatic steatosis, on suspicion of it being connected to a high-fat diet [16].

Burn patients constitute several clinical challenges for doctors and dietitians to achieve optimal nutrition therapy practice. In a prospective study in which the practices in burn intensive care patients were compared with the practices recommended in the American Society for Parenteral and Enteral Nutrition and the European Society for Parenteral and Enteral Nutrition dietary guidelines, it was reported that targets such as energy needs, using glutamine supplements, and daily protein requirements were achieved suboptimally [33].

Table 2. Micronutrient needs of burn patients [8, 35].

≤3 years old		> 3 years old	
Minor burn **<20% burns**	**Major burn** **≥20% burns**	**Minor burn** **<20% burns**	**Major burn** **≥20% burns**
1 Multivitamin /day	1 Multivitamin /day 250 mg/day Ascorbic acid 100 mg/day Zinc sulfate 5,000 IU/day Vitamin A	1 Multivitamin /day	1 Multivitamin /day 500 mg/day Ascorbic acid 220 mg/day Zinc sulfate 10,000 IU/day Vitamin A

2.4. Micronutrients

Not only are vitamins and minerals coenzymes and cofactors that enable better use of energy and protein, they are also compounds that promote wound healing and increase immune response [10]. Glucocorticoids that increase with prolonged bed rest increase demineralization together with hypoalbuminemia [17, 20]. In the clinic serum, sodium, potassium, chlorine, phosphorus, calcium, and magnesium minerals are monitored and manipulated with intravenous electrolyte solutions when necessary [21]. Regarding multivitamin supplements, it is deemed appropriate to consider the total nutrients and nutritional support the patients receive [34]. Children suffering from burns receive vitamin supplementation in the form of a multivitamin complex, in addition to vitamin C, zinc sulfate, and vitamin A in order to ensure adequate wound healing. The practical application of the micronutrient requirement in pediatric burn patients is shown in Table **2** [8, 35].

In 2015, a serious explosion occurred at an amusement park in Taiwan and a nationwide emergency occurred. According to a longitudinal retrospective cohort study conducted in a burn centre in Taiwan, it was reported that vitamins, calcium, and magnesium supplements contribute positively to wound healing, sepsis risk, and length of hospital stay [36].

In the examination of six articles conducted by the American Parenteral and Enteral Nutrition Association on the effect of nutrition on burn healing, 33% of the patients had Zinc deficiency and 48% had vitamin C deficiency. In conclusion, it has been reported that patients with burns should be supported for vitamin C, Zinc, vitamin D, and protein deficiencies [37]. It should not be forgotten that vitamins and minerals are given in suspension in tube feeding [34]. It has been reported that high amounts of vitamin C and Zinc increase nausea and vomiting [37]. Refeeding syndrome is a clinical picture that needs to be considered in the energy needs of all vitamin and mineral supplements [10].

2.5. Nutraceuticals

Nutraceuticals are non-toxic nutrients with scientifically proven health benefits in the treatment or prevention of diseases [38]. Arginine, glutamine, omega 3, and omega 6 fatty acids are among the nutraceuticals that have been studied in burn patients [21]. Arginine and glutamine are considered essential amino acids for patients with trauma. It has been reported that they provide nitrogen retention, wound healing, and the continuation of gastrointestinal system functions. Studies show that they also reduce bacterial translocation and sepsis. The use of glutamine was found to be useful in supporting immunonutrition. There are no definite recommendations for the use of arginine in septic or critically ill patients [30, 39, 40].

Omega 3 fatty acids are known to support the immune system due to their anti-inflammatory effect and vasodilatory properties. Use of omega 3 in burn patients is associated with an increase in muscle mass, the shortening of hospitalization time, improvement of the immune response, reduction of the frequency of diarrhoea, and improvement in glucose tolerance [8, 37, 41, 42].

On the other hand, with regard to omega 6 fatty acids, it is known that linoleic acid is the precursor of arachidonic acid metabolites that trigger inflammation. It is thought that a higher fat content than linoleic acid causes immunosuppressive effects and increases muscle breakdown. Therefore, it is recommended that omega 3 fatty acids in the diet should be higher than omega 6 fatty acids. It is also important to examine the omega 3 and omega 6 acid contents in the commercial formulas used [10, 21].

According to a study conducted in a burn center in India, hospital stays were shorter in patients who were followed up with a hospital formula based on cow's milk, rice, sugar, and a supplemental Vitamin C, B complex with trace elements like Zinc, Copper, and Selenium. On the other hand, patients were not given supplemental glutamine and arginine because of insufficient data regarding their effectiveness. As a result, an improvement in albumin and prealbumin levels have been reported. In this study, there is evidence that a well-planned dietary pattern is a palatable and cost-effective complement without requiring technologically advanced treatment [43].

CONCLUSION

In pediatric patients, it is crucial to evaluate the nutritional status of burn patients. Energy requirements of patients is evaluated by indirect calorimetry and sufficient energy is provided to deal with hypermetabolism. Protein intake has significant affects on wound healing. It is important to use supplements recommended for both major and minor burns in vitamin and mineral supplements. In cases where oral nutrition is not sufficient, artificial nutritional methods should be initiated as soon as possible.

The goal of patients with trauma is to achieve survival, tissue repair and to increase immunity. In addition to fluid, electrolyte replacement therapy, and various surgical interventions, nutritional therapy is also important. In nutritional treatment, it is necessary to provide appropriate energy and regulate the ratios of energy from carbohydrates, protein, and fat. Omega 3 and glutamine supplements have been reported as beneficial for nutrition in patients with burns. In cases where there is an energy deficit, enteral support should be the first choice. Parenteral nutrition can be used when necessary. Nutrition should be evaluated frequently by measurement of body weight, prealbumin, and C-reactive protein hepatic proteins. Nutritional evaluation tests in children can also be used in the follow-up. It is also important to monitor growth during and after the burn treatment.

A burn is a life-threatening preventable public health problem despite technological advances. While its mortality and morbidity are low in developed countries, it poses a problem for underdeveloped and developing countries. The most effective and inexpensive approach is to prevent burns before they occur. Educational institutions and media are needed, and awareness should be raised to prevent home accidents for children. Considering that some of the burns are related to child labour, substance addiction and attacks, the necessity of solving the problem with many disciplines becomes prominent.

CONSENT FOR PUBLICATION

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CONFLICT OF INTEREST

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