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Proteins in Human Nutrition: Executive Summary

Dietary proteins and human protein metabolism – basic aspects

Proteins are composed of 21 different amino acids in a definite sequence. Nine of the amino acids are strictly essential and cannot be synthesised within the body. In children, the amino acid histidine is also essential. Six amino acids are conditionally essential, and among the six remaining ones, alanine, glutamic acid and aspartic acid are entirely non-essential. Certain proteins have a high concentration of specific amino acids, for example proline in collagen, together with a very low concentration of the essential amino acids tryptophan and lysine. Animal proteins have usually a higher content of essential amino acids than vegetal proteins, resulting in a higher “biological value”.

At any state of N balance, there is a dynamic flux between whole body synthesis and whole body protein breakdown. During protein-deficient diets or during inadequate energy intake (Very Low Calorie Diet) leading to rapid weight loss, protein breakdown is greater than protein synthesis, so that body protein is lost, mainly by muscle catabolism.

Oxidation of amino acids leads in the liver to the formation of nitrogenous by-products such as urea (non toxic) and ammonia (toxic), both of which are excreted in the urine, where they constitute more than 90% of urinary nitrogenous compounds. The carbon skeleton of amino acids can be used as an energy source and as a substrate for the synthesis of glucose by gluconeogenesis e.g. during fasting and endurance exercise.

Protein synthesis requires energy (ATP) for peptide bonds. About 20% of the remaining heat production (energy expenditure) is accounted for by protein turnover.

Dietary protein consumption in Switzerland

Evaluation of intakes in Switzerland by food supply data yielded an average consumption of about 90 g/d per person, or 1.1 g/kg b.wt./d. About 2/3 of proteins were animal proteins with high biological value (meat and meat products (28%), milk and dairy products (28%), fish (3%), and eggs (3%), and about 1/3 of proteins were of plant origin (25% of total protein as cereals, 3-4% of vegetables).

Actual spontaneous protein consumption in Switzerland by specific groups of subjects is well within the actual recommendations (10-20% of energy). Frail elderly subjects may be at risk of not covering their requirements for protein.

Agricultural production of animal compared to vegetal protein represents a higher ecological burden (required land size, water consumption, production of greenhouse gases etc.). Therefore, the amount of protein consumption not only has an effect on the health of the population as outlined below, but also has a socioeconomic and ecological impact. However, these two latter aspects will not be covered in this report because they are not the focus of this publication.

Dietary protein requirements – general comments

The physiological protein requirements are classically determined by N balance studies (intake expressed as N minus total N output). There may be additional protein needs due to anabolism (growth, pregnancy, "regrowth"). Protein requirements or protein recommendations are generally expressed either in relative terms (g/kg b.wt./d) or relative to energy (% of total energy).

The first protein requirement estimate dates back to before World War II (1.0 g/kg b.wt./d). It was higher than the value of 0.8 g/kg b.wt./d recommended later for almost 4 decades. Today, recent but not yet official recommendations appear to return to the earlier figures (1.0/kg b.wt./d). All these recommendations do not distinguish between sexes and age groups - which is obviously a limitation due to lack of adequate scientific data in these subgroups.

Human protein needs have been calculated on the basis of different criteria by different expert committees. Thereby, various terminologies have been applied. Frequently used terms are: Recommended Dietary Allowances (RDA), Protein Requirement (PR), Reference Nutrition Intake (RNI), Population Reference Intake (PRI), Average Requirement (AR), Dietary Reference Value (DRV), Recommended Daily Nutrient Intake (RDNI), Dietary Reference Intake (DRI), Acceptable Macronutrient Distribution Ranges (AMDR), Optimal Intake (OI), Safe Level of Protein (SLP), Tolerable Upper Intake level (TUI), Lowest Threshold Intake (LTI).

Protein requirements in children and adolescents

Protein requirements in children have been suggested to be approx. 10 g/d at the age of 6 months, increasing at 15-18 years to 58 g in boys and to 47 g in girls, respectively (WHO). However, the actual intake of proteins in children and adolescents is much higher; at 13-15 years - according to a European review - it is about 100 g/d or even more.

Excessive amounts of protein associated with increased energy intakes in infants and small children increase the risk for overweight and obesity.

If at the age of 5-6 years the intake of total protein, and especially that from animal sources, is too high, puberty may start earlier in girls and boys.

Protein requirements in adults

The present official dietary requirements for healthy adult women and men for all age groups are 0.80 g (high quality) protein per kilogram bodyweight. For a normal-weight man (70 kg b.wt.) this corresponds to 56 g/d, and to 46 g/d for a 57 kg woman, respectively.

In pregnancy the minimal protein requirement has been stated to be 1.1 g/kg b.wt./d, and during lactation 1.3 g/kg b.wt./d, respectively.

A concomitant adequate energy intake from non-N-energy sources is a prerequisite for the present recommendation.

Protein requirements in the elderly

The current recommendation for protein intake of healthy elderly people is the same as for younger adults (0.8 g/kg b.wt./d). Despite conflicting evidence and a controversial debate among experts in recent years about these recommendations, the WHO/FAO/UNU expert committee recently confirmed them, irrespective of sex and age.

However, adequate protein intake and the maintenance of nitrogen equilibrium is of particular importance in the elderly because this age group is at increased risk of illness and malnutrition, and very little is known about the protein needs of the frail and unhealthy elderly. The role of protein intake in bone health is dealt with in a separate chapter.

There is general agreement that protein anabolism can be stimulated by moderate amounts of dietary protein. Protein anabolism is also affected by eating patterns and physical activity.

Some suggest that not all elderly subjects can achieve nitrogen balance with 0.8 g/kg b.wt./d protein. However, there are at present no studies convincingly showing that protein requirements of the elderly differ substantially from those of younger adults. Until more evidence is available, it seems reasonable to ensure a protein intake of at least 0.8 g/kg b.wt./d in all elderly people, particularly in those at risk of malnutrition (e.g. frail and multimorbid elderly).

Early recognition of nutritional difficulties is crucial. Adequate protein and energy intake should be ascertained, along with encouragement of physical activity in order to facilitate muscle protein anabolism.

Dietary proteins in sports

The daily intake recommendations for adult athletes suggested by most of the entities are about 1.5 g/kg b.wt/d, with a range of approx. 1.0-2.0 g/kg b.wt/d. Distinction of dietary protein recommendations in strength and endurance athletes is no longer supported by most authorities today.

Research over the past decade indicates a beneficial effect with respect to a positive net muscular protein balance if athletes ingest some protein (about 10 to 20 g/h) before an exercise bout.

The Swiss Food Pyramid for Athletes represents food-based recommendations which ensure a sufficient intake of energy and micronutrients in relation to the daily exercise volume and intensity. It emphasises the need to coordinate protein intake with that of other nutrients.

Dietary proteins in obesity and in diabetes mellitus

Dietary proteins influence body weight by affecting satiety, thermogenesis, energy efficiency, and body composition.

Protein ingestion results in more satiety than aequicaloric amounts of carbohydrates or fat. Their effect on satiety is mainly due to oxidation of amino acids fed in excess; this effect is higher after ingestion of “incomplete” (vegetal) proteins than after animal proteins.

Diet-induced thermogenesis is higher for proteins than for other macronutrients - energy expenditure (thermogenesis) increased by 20-30% after proteins compared to 5-10% after carbohydrates and 0-5% after ingestion of fat. This increase in energy expenditure is caused by protein and urea synthesis and to gluconeogenesis; this effect is larger after animal than after vegetal proteins.

Energy restricted high protein diets in obesity (protein amounts of approx 30% of total energy, or 1.2 g/kg b.wt./d, versus 15-20% of total energy, or 0.8 g/kg b.wt./d) resulted in greater weight loss or in less weight regain after weight loss than diets with lower amounts of protein in studies lasting up to one year. These high protein diets during weight loss maintained fat-free mass (i.e. muscle mass) and increased calcium balance, resulting in the preservation of bone mineral content.

Adequate dietary protein intake in diabetes type 2 is of specific importance since proteins are relatively neutral with regard to postprandial serum glucose and lipid concentrations, and they preserve muscle and bone mass which may be decreased in subjects with poorly controlled diabetes.

An adverse effect of increased dietary proteins such as progression of renal insufficiency has been observed in subjects with kidney diseases - this problem is quite often observed in the elderly, hypertensive and diabetic population.

Dietary proteins and bone health

Dietary proteins may prevent osteoporosis, in addition to dietary calcium and vitamin D. Dietary protein intake was correlated with bone density and mineral content.

Hip fracture incidence was lower during high protein diet (1.3 g/kg b.wt./d) compared to lower protein intake (1.0 g/kg b.wt./d). An intervention study indicated that following orthopaedic management, protein supplementation attenuated post-fracture bone loss, tended to increase muscle strength, reduced medical complications and the duration of rehabilitation.

In the elderly, taking into account the attenuated anabolic response to dietary protein with aging, there is concern that the current dietary protein RDA, as set at 0.8 g/kg b.wt./d, might be too low for the primary and secondary prevention of fragility fractures, and expert groups specialised in bone health stated that approx. 1.2 g protein/kg b.wt./d would be more appropriate.

Protein catabolism and requirements in severe illness

Severe illnesses are characterized by reduced total body protein mass, mainly due to diminished skeletal muscle mass. Protein-energy malnutrition has been associated with increased mortality.

Severe illnesses are characterised by increased protein breakdown and, to a lesser extent, by an increase in whole-body protein synthesis, associated with an increased flux of amino acids from the periphery to the liver.

Nutritional support limits but does not abolish the loss of total body protein mass occurring in acute severe illness. Protein intakes between 1.2 and 1.5 g/kg b.wt./d with neutral energy balance minimise body protein loss. Glutamine and possibly leucine may improve clinical outcomes.

Present recommendations indicate a caloric supply of 20-25 kcal/kg b.wt./d over the first 72-96 hours and an increase in energy intake as the target thereafter. Simultaneously, protein intake should be between 1.2 and 1.5 g/kg b.wt./d.

Tube feeding (enteral nutrition) with "immunonutrients" enriched with arginine, nucleotides and omega-3 fatty acids is indicated in patients with trauma, acute respiratory distress syndrome (ARDS) and mild sepsis. Glutamine (0.2-0.4 g/kg b.wt./d of L-glutamine) should be added to enteral and parenteral (intravenous) nutrition in burned and trauma patients according to current guidelines.

Dietary proteins and atherosclerosis

More than 100 years ago the hypothesis "protein" of the pathogenesis of atherosclerosis and its association with cardiovascular disease was put forward on the basis of animal experiments; however, it has never been verified so far in humans.

Epidemiological studies in the 1960s showed significant associations between dietary animal protein and mortality from cardiovascular disease. However, animal protein intake was also significantly correlated with saturated fatty acid and cholesterol intake. In contrast, in the last decades two prospective cohort studies demonstrated a decreased cardiovascular risk in women during high versus low protein intake when the dietary intake was adjusted for other factors (e.g. saturated fats) and for cardiovascular risk factors.

The Mediterranean diet has been associated with diminished risk of coronary heart disease; this diet has a pattern which is characterised by relatively high amounts of plant-derived food and of fish as alternatives to meat and dairy products.

Protein intake in renal and hepatic disease

The amount and composition of ingested proteins has a direct impact on renal function, especially in kidney disease, and on the risk of kidney stones. Limitation of ingested protein, particularly from animal sources, is therefore crucial in order to slow down the progression of chronic kidney disease and the impairment of renal function. In contrast, patients with chronic renal failure undergoing renal replacement therapy by haemo- or peritoneal dialysis have an increased protein demand. The syndrome of “protein-energy malnutrition” is a relevant factor for morbidity and mortality in this population, requiring early detection and vigorous treatment.

Protein intake in patients with cirrhosis of the liver should not be decreased as suggested earlier but rather increased to counteract the risk of protein malnutrition. Only in patients with advanced hepatic encephalopathy has there been recommended moderate restrictions depending on protein tolerance, with the possible addition of branched chain amino acids (BCAA).

Allergic reactions to food proteins

Four to eight percent of the population have food allergies, and the prevalence rates are increasing in the past years. Most food allergies are against food-derived proteins and they are usually acquired on the basis of a cross-reaction to pollen allergens. Theses allergens are ubiquitous in the plant kingdom. Therefore pollen-allergic patients might acquire a multitude of different plant food allergies and even react to novel foods, to which they have never been exposed before.

A curative therapy for food allergy does not yet exist. Food-allergic patients have to rely on strict avoidance of the suspected foods. The widespread use of industrially processed foods poses a general problem for food allergic patients. Although the most frequent allergens must be declared openly in the list of ingredients, involuntary contamination with allergy-provoking compounds can occur. The labelling “may contain...” discourages consumption even if the chance of contamination is negligible; on the other hand, the allowance of up to 1 g/kg b.wt./d of allergy-provoking compounds without need for declaration may be too high to protect food allergic individuals if traces of these foods already cause symptoms.

Bioactive proteins and peptides in foods

An increasing amount of data demonstrates specific effects of dietary proteins and peptides beyond their nutritional impact (“bioactivity”). The focus of the investigations has mainly been on vitamin- and mineral-binding proteins, on antimicrobial, immunosuppressing/-modulatory proteins, on proteins with enzyme inhibitory activity as well as on hormones and growth factors derived from food proteins. Most research has been performed on milk proteins.

Biologically active peptides are released during fermentation or digestion of food proteins; these peptides are mainly found in milk, and they exert opiate-like, antihypertensive, mineral-binding, antioxidative, antimicrobial, immuno- and cytomodulating activity.

Intact absorption of these smaller peptides is possible; therefore organs outside the gastrointestinal tract are possible targets for their biological effects.

Bioactive proteins and peptides are normal parts of a balanced diet. However, it is possible to accumulate bioactive peptides in food, for example by using specific microorganisms in fermented dairy products. Although bioactive peptides have been the subject of several investigations *in vitro* and *in vivo* in humans, their health potential is still not clearly established. Therefore, the Commission of European Communities has not (yet) authorised any health claims for bioactive proteins and peptides from food.