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Case Report

The Connection between Food and Exercise: Historical Issues and Future Perspectives

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Abstract

In ancient times, physical activity was necessary for food procurement, which in turn was required to ensure biological survival of our species. Hence, during cycles of feast and famine, certain genes evolved to regulate an oscillating enzymatic control of fuel storage and guarantee survival. Over time, with social and environmental changes, this relationship assumed a nature no more than evolutionary importance, but finalized to enhance the physical performance. According to the new vision of the connection between food and exercise, dietary habits in athletes depend on country origin, type, environmental condition, and type, duration and intensity of the sport; although there are still some unresolved questions as the role of protein, carbohydrate requirements, and vitamin and antioxidant needs. Currently, in order to promote physiological adaptation during agonistic performance, sport nutrition focused attention also on training sessions. This concept is accompanied by new guidelines and recommendations suggesting that the requirement for carbohydrates (daily ranges from 6 to 10 g/kg) and proteins (daily ranges from 1.2 to 1.7 g/kg), should meet the individual needs of the athlete in relation to the period of competition and to everyday situation in which intensity of training needs to be taken in consideration. From this point of view, an integrated perspective in which dietary regimen and exercise are intimately tied by a bidirectional link towards a personalized nutritional strategy, could be an important aspect to improve performance, well-being and trauma prevention in athletes

INTRODUCTION

The relation between food and exercise changed completely with human evolution. In the past, the approach to diet was mainly oriented to guarantee fuel to perform physical activity of the athlete in a way that was independent from personal metabolic and physiological response to exercise and also from the type of sport practiced (aerobic, anaerobic, or both). Currently, nutrition in athletes is acquiring a key role in the perspective to increase performance, reduce traumatic injury and increase recovery after performance. In this perspective, food is considered not only fuel for exercise, but also a way to increase adaptive physiological response to exercise training. This review is focused on the evolutionary relationship between food and exercise in the times taking into account the new potential perspectives offered by new dietetic opportunities and the orientation to personalize dietetic regimen for each athlete.

Food and exercise: the need to survival

The importance of nutrition in sport has been recognized since the ancient Olympians. In ancient times, food and physical activity, basic necessities to ensure the survival of most animal species and our ancestral progenitors in the "wild", were closely interrelated and could not be disassociated from each other, not only because of energy need, but also because of the profile of food components which allow, sustain and optimize movement. During evolution, biological existence of our species was dependent by food supply, which in turn was dependent on physical activity [1]. The ancient hunter-gatherer interchanged periods of feast (during food abundance) with famine (under drought conditions or inability to hunt due to physical inactivity or illness), resulting in cycles of physical activity and rest. In these conditions, energy was stored as glucose and glycogen to overcome the problem of the discontinuous nature of intake compared with the continuous demand, where intake was also adjusted to meet immediate changes in demands. On this basis, Neel [2] proposed the notion of "thrifty genotype" in which, during periods of famine, to ensure survival and to maintain homeostasis via "physical activity cycle" certain genes evolved to efficiently regulate an oscillating enzymatic control of fuel storage and use during feast/famine and physical activity/rest cycling [3]. In this context, insulin resistance during metabolic derangement represents a central feature, because the onset of a certain degree of insulin resistance give advantages both during the periods of famine and reefed (including increased fat oxidation for energy, attainment of a certain "glycemic stability", and muscle glycogen conservation) [4]. An efficient storage of fuel and, more important, its efficient utilization allow availability of energy when the necessity for food requires intense physical activities to cover great distances and hunt despite a prolonged fasted state [3]. Once the hunt was completed, feast once again occurs, and the exhausted fuel stores were restored for another cycle. From a Darwinian point of view, if in ancient times the relationship between food and physical activity was aimed to allow the survival of the species, with social and environmental changes, this relationship assumed a nature no more than evolutionary importance. In fact, during the past century, this new connection between food and exercise underwent further changes due to industrialized societies that have made progress so that food could be produced with minimal physical work compared with earlier centuries. Hence, the combination of food abundance and physical inactivity eliminated the evolutionarily programmed biochemical/metabolic processes due to feast-famine and physical activity-rest cycles.

Food and exercise: the fuel to better performance. Historical background

The close relationship between food and exercise no longer intended to ensure the preservation of the species, but to enhance the physical performance, was reinforced by the history of the food supply through time at the Olympics Games at Athens, which represents an interesting insight into the evolution of sports nutrition research and the dietary strategies of athletes [5].

In particular, although numerous descriptions exist of special diets used by Greek athletes as early as 580 B.C., it is impossible to identify precisely when meat became a major component of athletes' diets, although the diet of ancient Greek athletes is largely legendary. The best report of athletic diet was related to Milo of Croton, a wrestler who won five successive Olympics, with a diet composed by 9 kg of meat, 9 kg of bread and 8.5 L of wine a day, which suggested an improbable intake of 57,000 kcal/day. Survey data on dietary intake of Olympians are sparse, however, until the end of '60th, the intake of protein was preferred [5].

Although modern athletes have exceed their ancient counterparts in some disciplines such as running and swimming faster, throwing farther, and lifting heavier weights, generally, athletes through the centuries have striven for the same objective: success and victory. This dual search, the ambition for success and better performance and a personal best, has also been accompanied by the search for a nutritional competitive contribution.

Some evidence pertaining to the last century still reveals wide variation in dietary habits of elite athletes, essentially depending to country origin and local food behavior, type, duration and intensity of the sport or training undertaken, fitness and training status, gender and environmental conditions.

One of the first nutrition-related studies on athletes was conducted on 1952 in Helsinki Olympiad where the percentages of energy from carbohydrate, protein, and fat ranged from 33 to 57%, 12 to 26%, and 29 to 49%, [6]. Progressively changes occurred during the period from 1970 to nowadays with reduction of beef, egg, and milk consumption, towards a higher-carbohydrate diet and lower-fat food [7]. In fact, the use of carbohydrates has been largely emphasized due to the evidence of a clear benefit on physical performance [8].

Although many athletes, over the years, have used special diets and particular foods in their training program, there are still some unresolved questions as the role of protein, carbohydrate requirements, and vitamin and antioxidant needs.

In the 1990s, official guidelines recommended high carbohydrate intakes during the everyday training, thus suggesting approximately a 60% of the consumed energy by carbohydrate intake. This favors daily muscle glycogen recovery, and is able to reduce the development of over-reaching symptoms [9].

Until recently, the primary target of recommendations and practices in sport nutrition was focused on the recovery from training sessions in order to allow the athletes to undertaken intensive training programs without succumbing to illness and chronic fatigue. From this point of view, nutrition to improve sport performance aimed to underline the role of a high daily carbohydrate and fluid intakes to ensure replacement of sweat losses. More recently, however, there has been a shift towards looking for ways in which sports nutrition can help to promote the physiological and biochemical protective mechanisms of adaptation during the training sessions. It is possible in fact that nutritional strategies, in particular the intake of macronutrients and micronutrients, can modulate the adaptive response to training, especially those affecting the muscles via activation of the AMP-activated protein kinase (AMPK) [10]. It is generally assumed that the optimal adaptation to the repeated training sessions requires a diet that can sustain muscle energy reserves. In this context, protein supplementation is required to maximize the adaptive response of the skeletal muscle to prolonged resistance-type exercise training [11]. A recent meta-analysis including a total of 22 studies with 680 subjects, both young and old subjects, confirmed that protein supplementation is useful to increase muscle mass and strength during resistance training in both young and older subjects [12]. However, the large discrepancy of the results on the effects of protein supplementation, depending on the differences in the study design variables – age and type of population enrolled, training status, type and duration of supplemental intervention and exercise – suggests that not all the nutritional approach are beneficial to promote adaptation to exercise, and thus this type of intervention should has to be personalized in regard to the athlete and the sport performed. Also, there are conflicting results on the effects of vitamin C and E supplementation on adaptation to exercise [13]. This evidence in human is further confirmed in experimental studies showing that the metabolic adaptations to training, consisting in increased muscle oxidative capacity coupled with the proliferation of a mitochondrial population with decreased oxidative capacity, were generally prevented by antioxidant supplementation [14,15]. These negative findings may be interpreted in the sense that external antioxidant supplementation, cannot equalize but, in some cases, even counteract the beneficial effect of the "natural" antioxidant effect of exercise on the oxidative stress as well as on the other muscular, metabolic and cardiovascular beneficial adaptive mechanisms. Generation of reactive oxygen species during exercise may promote the expression of several proteins that represent the molecular basis of the exercise-induced hormetic response, whereas antioxidant supplementation can lower the concentration of ROS beyond this required level and produce adverse consequences [16]. Other difficulties in predicting the final effects of antioxidant supplementation include the consideration of a number of variables such us type of antioxidant utilized, mono- multi-antioxidant administration, dose and duration time of the treatment [17].

Food and exercise: Future perspectives

It is general position that physical activity, athletic performance, and recovery from exercise and trauma are enhanced by optimal nutrition. Some general indications have been produced by scientific Societies. For example, according to the International Association of Athletics Federation, carbohydrate intake is the main energy provider macronutrient for the athletes and the daily dosage is in relation to the period of competition, acute (early before, 3 days before, the day of the competition, and early after competition) and in chronic or everyday situation in which intensity of training needs to be taken in consideration [18]. Currently, the general consensus on macronutrients intake is that carbohydrate loading ranges from 6 to 10 g/kg (2.7 to 4.5 g/lb) body weight per day, the amount of protein ranges from 1.2 to 1.7 g/kg (0.5 to 0.8 g/lb) body weight per day [19]. Fat intake should range from 20% to 35% of total energy intake, taking into consideration that consuming <20% of energy from fat does not benefit performance [19]. However, the main problem to face is which diet for each subjects in different training periods and during lifespan, as beyond the general guidelines on the macronutrients intake in athletes, nutrition would be personalized for the athlete's energy expenditure and the type of sport. Regarding the first point, the assessment of basal metabolism as well sport kin anthropometry may provide useful information on body mass and composition, perimeter and skin fold and somatotype in order to personalize diet for each athlete [20]. Another point is the age of athletes, considering the high number of aged athletes, in particular performing endurance sports and the change of nutritional requirements with aging [21]. The type of sport is relevant in the nutritional intake decision making. In this context, it is important whether the sport is predominantly aerobic or anaerobic or sprint, resistance endurance, as well as the duration and the place, that is on earth or sea. In this context there are several studies assessing food intake in different type of sports, swimmers, soccer players, weightlifters, marathon and ultra marathon runners, and cyclists [22]. Moreover, other aspects such as the training period, training level and sex of the subjects, environmental conditions and inter-individual differences influence the nutritional needs [23]. In addition, food can also influence the health of brain improving performance and determining a positive action on neuronal function and plasticity [24]. From this point of view, exercise has been shown to interact with dietary strategies, increasing the positive effects on brain functioning, crucial to improve the agonistic performance, and decreasing fatigue (Figure 1).

There is a large literature showing the benefit of nutrients supplementation in athletes [25,26]. However, according to the statement position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine, there is no indication to take supplementation when athlete is consuming full well-balanced diet. Vice versa, a multi vitaminic/ mineral supplementation is appropriate if athletes follows diet to lose weight, or has micronutrients deficiencies or is recovering from injury [19].

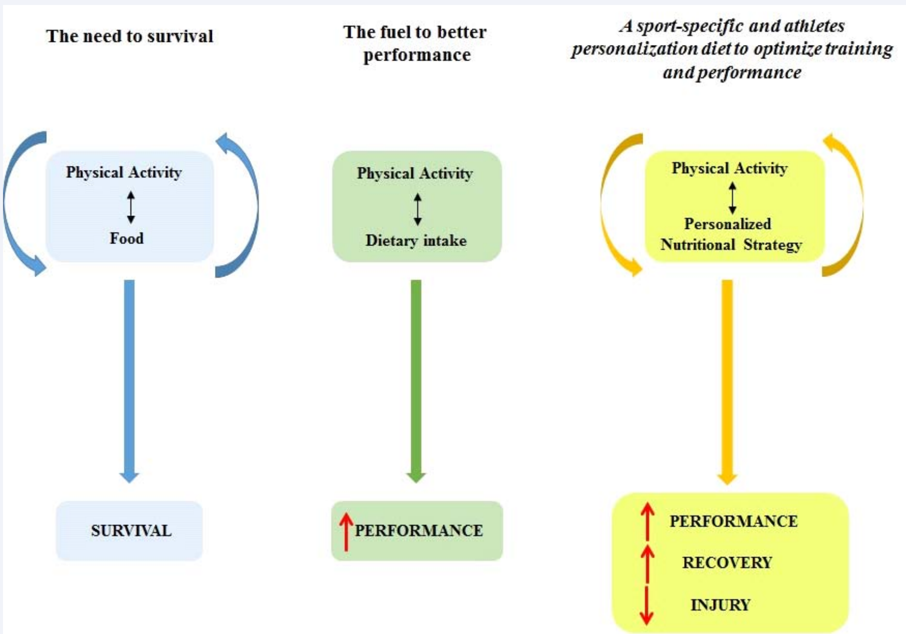

Figure 1 Representation of hypothesized connection between food and exercise in past, present and future.

Also, caloric restriction has been shown to have beneficial effects on cardiac function, such as decreased blood pressure, serum C-reactive protein, and tumor necrosis factor-α [27], and for these reasons could be considered as nutrition strategies to maximize sports performance, although the impact of this approach on exercise performance is less clear. Caloric restriction during training is common among lean athletes to improve body composition for competition. Despite the high frequency of lean athletes restricting calories during the training program, studies and results in which these conditions are examined are poor and unclear. In fact, while exist recommendations and guidelines for carbohydrate, protein, and fat intake, positions and statements point out the requirements for athletes that consume restricted diets are less commonly. To this regard, it is also important to remind that an inappropriate application of caloric restriction may cause malnutrition or compromised intake of key nutrients, with potential severe adverse health effects.

In the future perspective, Mediterranean diet, for its proven protective/beneficial effects on health, characterized by a high intake of vegetables and fruits, legumes, cereals, fish, low intakes of meat and dairy products, moderate consumption of wine, and extra virgin olive oil consumption, may be a suitable candidate among different dietary regimen towards a personalized sport nutrition assessment [28].

At present, available data on the Mediterranean diet are essentially related to aging prevention, metabolic and degenerative diseases. To our knowledge there are few data in the literature on the effect of adherence to the Mediterranean diet in athletes [29]. Thus, more data related to adoption of Mediterranean diet and its effects in sport activity in terms of performance enhancement and pathological risk are needed, at this point, to clearly define possible beneficial effects of this dietary regimen. Also, Mediterranean diet, recognized by UNESCO in 2010 as a cultural heritage of Humanity, highlights other aspects other than food, such as conviviality, socialization, biodiversity and seasonability and could represent in sport nutrition a new model to improve performance, well-being and disease prevention in athletic population.

CONCLUSION

Nutrition and exercise, two main fundamental activity in the human history, remain closely intermingled, although their relationship has changed nowadays completely from the past, and currently moving towards a personalized approach for each single athlete. However this is still an opened chapter in which several points need to be defined:

- The impact of new dietary regimens, like Mediterranean or enriched diet, for example with natural antioxidant, or caloric restrictive diet, on performance and injury prevention
- The role of full diet in respect to macro and micro nutrients supplementation, also in regard to the adaptive processes induced by training
- The development of methods to personalize nutrition in respect to the individual energetic needs and personal and environmental characteristics of the athlete has to be defined.

Currently, according to the International Association of Athletics Federation, carbohydrate intake is the main energy provider macronutrient for the athletes and the daily dosage is in relation to the period of competition and training.

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