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Biomarkers of Nutrition, Metabolic Health and Food Allergies of Athletes: A Review

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Abstract

Aim: The aim of this review was to discuss the role of biomarkers of nutrition, metabolic health and food allergies of athletes. **Results:** The research in the field of nutrition, metabolic health and food allergies has identified various biomarkers for assessing athlete's nutrition status metabolic health and performance. However, there are biomarkers which changes in individual's participating in physical activity and exercise training programs. In the present review an approach was to review the current literature of nutrition, food allergies and determined a set of validated biomarkers of nutrition and metabolic health of athletes that could be used by coaches and trainers. **Conclusion:** The present review will help sport scientists, coaches, trainers, clinical sport professionals, researchers, and athletes to better understand how to monitor biomarkers of nutrition, metabolic health and food allergies of athletes, as they can better evaluate performance, modify training and identify nutritional deficiencies that elicit maximal improvements in athlete's performance.

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Introduction

The performance of an athlete and his\her recovery from exercise is improved by optimal nutrition according to a joint position stand by the American College of Sports Medicine (ACSM), Dietitians of Canada and the American Dietetic Association (ADA).When nutritional intake is insufficient functional performance of athlete is impaired and a high incidence of disordered eating in athletes, in particular female athletes contributes to concerns about general health. Specific dietary or nutritional deficiencies are very common in athletes particularly for iron and vitamin D for which studies have reported deficiency rates of 73% (Constantini et. al., 2010) and 22-31% (in female athletes) (Dubnov and Constantini 2004; Risser et. al., 1988).Other, less common nutritional deficiencies in nutrients such as folate, vitamin B12, or magnesium may result in reduced endurance work performance and muscle function in athletes. Individual nutritional requirements of athletes depend largely on type of sport activities and training specific bioenergetics demands as well as on an athlete's metabolic tolerance, needs and preferences. Frequent monitoring of nutrients (macronutrient and micronutrient) intake in athletes may help recognize individual deficiencies and track changes, especially as training volume and nutritional demands increase. Nutritional measurement by objective biomarker testing eliminates partiality associated with more traditional and subjective nutritional assessments (e.g. three day recall method, questionnaire).

Glucose, Fat and Protein

Glucose functions as the principal energy source in human body. Unlike fats and proteins (e.g., ketones), which the body uses them as energy sources in some circumstances, glucose is the only energy substrate in the body that functions exclusively for providing energy to cells. Circulating glucose levels during exercise depend on energy status, glycogen storage levels, intensity of exercise and food intake. Decresed glycogen availability is generally related with fatigue. With glucose-depleting events, carbohydrate eating before or during prolonged exercise has been shown to restock glycogen, keep blood glucose levels, and increase performance, in particular for high-intensity activity (Vandenbogaerde and Hopkins 2011). Tracking and monitoring fasting and longer-term blood glucose through biomarkers such as glucose may aid individual athletes monitor the nutritional sufficiency of their diet? Although fasting blood glucose is not frequently associated directly to performance, athletes tend to have lower fasting blood glucose (Lippi et. al., 2008), where levels are related with the intensity of the training regimen (Lippi et. al., 2008). A sufficient nutrition for a given training volume can decrease the risk of exercise-induced hypoglycemia in athletes. Additionally, exercise training may decrease susceptibility to hypoglycemia in athletes because of a shift in substrate metabolism. However, overtraining may reverse this adaptation, making athletes more susceptible to hypoglycemia in the over-trained state.

Fats are used as a principal energy source in endurance actions or when carbohydrate/ or glucose availability is low. Especially, medium-chain fatty acids are preferred for oxidation, as they enter circulation more quickly and are chiefly absorbed by the liver. Fat burning up during exercise impacts lipid profiles by dropping resting levels of total cholesterol and triglycerides (Hong and Lien 1984), thereby improving cardiovascular health profiles. Besides to providing energy, a few types of fats play significant roles in recovery. Omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) decrease inflammation, muscle soreness, and the perception of pain from exercise (Jouris, et. al., 2011; Bloomer et. al., 2009; Tartibian et. al., 2009). Furthermore, omega-3 fatty acids may influence performance of athlete through their effects on neuromuscular function (Stiefel et. al., 1999), neuromuscular sensitivity of the acetylcholine receptor and nerve conduction velocity (Stiefel et. al., 1999). In addition, omega-3 fatty acids may keep up increased training volume (Jouris, et. al., 2011) and support adaptations to exercise training. Levels of Omega-3 fatty acids measured in the blood reflect their clinical role more so than dietary intake. however, the recommended daily intake of omega-3 fatty acids (EPA+DHA) is ≤ 3 g.d.$^{-1}$ for average individuals or those moderately physically active, but recommendations may be as high as 6-8 g.d.$^{-1}$ (2:1 ratio of EPA:DHA) for elite athletes. Greater training demands may increase requirements for omega-3 fatty acid intake.

Proteins act as the building blocks of enzymes and hormones used in all cells and tissues in the body, including muscle. In general, protein intakes of 1.3–2.0 grams per kg body mass per day are recommended for athletes to support muscle protein synthesis, make easy training adaptations, and stop lean muscle mass loss. A disproportion between dietary protein intake and dietary protein needs may consequence in net protein loss in athletes. With protein shortage, tissue protein breakdown becomes a source of essential amino acids needed to maintain critical body functions. Although, it is commonly known that athletes need higher protein intake than the recommended daily allowance (RDA), defining individual needs is challenging. As described below, a combination of biomarkers including total protein, albumin, globulin (calculated), blood urea nitrogen (BUN)] or urinary urea nitrogen, nitrogen balance (calculated) and amino acid analysis may facilitate athletes to measure their protein status and make dietary alterations to get better training outcomes. Protein insufficiency decreases blood proteins, in particular of albumin, and low protein intake seems to reduce the rate of albumin synthesis (James and Hay1968). However, albumin may also serve as a marker of other aspects of athlete health and performance, and this gauge requires contextualization when assessed in athletes. The need for contextualization is a general characteristic of numerous biomarkers in a comprehensive panel approach to tracking biomarkers and performance of athlete. Contextualizing albumin levels, conventionally defined for sedentary or non-athlete populations, for athletes training or competing is vital for interpreting the implications of either decreased or elevated plasma albumin. Besides, it is significant to comprehend that measures such as albumin may also be associated to performance and recovery through nontraditional functions or signaling in athletes. For example, albumin has been linked with human growth hormone (GH) concentrations in the blood (Pimstone et. al., 1968) and while the mechanism by which these two markers are related is unknown, this kind of result suggests that albumin may need extra reading when tracking athletes. Similarly, while urea nitrogen (blood or in urine) is a product of protein degradation and suggests protein breakdown, elevations can be caused by a variety of factors such as protein intake, endogenous protein catabolism, fever, infection, glucocorticoids, state of hydration, hepatic urea synthesis and renal urea excretion. Lower urea nitrogen may be due to low protein intake, malnutrition starvation, or impaired metabolic activity in the liver. Higher urea nitrogen may be due to exhaustive exercise training, catabolism (Hong and Lien 1984), and high dietary protein intake (Young et. al., 2000). While maintaining a positive protein balance is essential to facilitating finest recovery and training adaptations, protein status should be optimized to avoid nutritional insufficiencies and too much protein catabolism. In the nonexistence of disease, low blood protein, low albumin, and elevated urea nitrogen may be indicative of inadequate protein intake in athletes. In conditions where protein intake seems to be adequate for an athlete's estimated needs, albumin and urea nitrogen may specify other pertinent athlete health issues. Numerous athletes pursue nontraditional diets, such as low carbohydrate or ketogenic diets. Athletes are competent to keep up performance on diets comprising as little as 7% carbohydrates without effects of gluconeogenesis (Webster et. al., 2016), but dramatic effects on fat oxidation to maintain similar muscle glycogen use and repletion to that of athletes on traditional high carbohydrate diets (Volek et. al.,2016). As with all biomarkers, we urged contextualizing nutritional biomarkers with each individual's habitual diet in a dynamic fashion. In other words, absolute values for certain biomarkers may not direct action for a given athlete, but changes with training that coincide with reduced capability to recover and decreased performance should be monitored on an individual basis. This approach to biomarker monitoring will permit coaches and staff to better observe groups of highly variable athletes who will inevitably have highly different diets and other behaviors that affect performance.

Vitamin-D, Vitamin-B complex, Vitamin-E, Minerals - Magnesium, Iron, Folic acid, Zinc and Chromium

A variety of vitamins and minerals support physiological processes that be the cause of performance. For instance, ***Vitamin D***, in addition to being involved in bone upholding, has a role in muscle function and protein synthesis. A lot of athletes observe vitamin D with a goal of achieving levels of greater than 50 $ng.ml^{-1}$ because a number of potential ergogenic effects of vitamin D on sport performance (Dahlquist et. al., 2015). While a few studies have determined that specific vitamin D supplementation regimens do not affect power-specific performance variables, there is promising proof that vitamin D supplementation enhances aerobic performance (Jastrezebski 2014) and that vitamin D levels are linked to aerobic performance (Dahlquist et. al., 2015). The ***B-complex vitamins*** (thiamin, riboflavin, niacin, pyridoxine, folate, biotin, pantothenic acid, and choline) also play a significant role in performance by regulating energy metabolism by modulating the synthesis and degradation of carbohydrate, fat, protein, and bioactive compounds. In addition to B-complex vitamins, other vitamins play an important supporting role in recovery processes. For instance, vitamin E functions as an antioxidant in cell membranes and subcellular structures (Kanter 1994).Deficiencies in vitamin E may relate to neurologic damage and erythrocyte hemolysis, as well as muscle degradation (Lukaski 2004). Likewise, beta-carotene, a precursor of vitamin A, acts as antioxidants in reducing muscle damage and enhancing recovery after exercise (Kanter 1994). The Low B-vitamins, vitamin D, calcium and iron have been linked with increased injury risk, specifically lower extremity stress fractures (McClung et. al., 2014). A number of essential minerals for example magnesium and iron, affect physical performance (Lukaski 2004). For instance, ***magnesium*** is significant for energy metabolism as well as nerve and muscle function (Lukaski 2004). Deficiencies may lead to muscle weakness (Lukaski 2004), muscle spasms (Flink 1981) and altered CK and lactate response to exercise (Golf et. al., 1998). In addition, specific nutrients including ***folic acid***, vitamin B12 (cyanocobalamin) and iron, are essential to hemoglobin synthesis and subsequently oxygen transport (Lukaski 2004). Deficiencies may lead to anemia, immune deficiencies, cognitive impairment and fatigue (McClung et. al., 2014; Lukaski 2004). ***Iron*** deficiency is prevalent in athletes from a variety of sports (Lukaski 2004 ; Risser et. al., 1988), with incidence as high as 31% in some sports (Risser et. al., 1988). In addition to decreased iron concentrations, other biomarkers are useful in the assessment of iron deficiency including ferritin (concentration less than 12 $mg.L^{-1}$) and transferrin (saturation less than 16%) (Lukaski 2004). Moreover, red blood cell indices may provide early indications of nutritional deficiencies. For instance, red blood cell, hemoglobin and hematocrit indices may suggest iron, vitamin B12, or folate deficiency (Lukaski 2004).Other micronutrients including zinc and chromium also have significant supporting roles in metabolic health in athletes. ***Zinc*** is necessary for a variety of functions including protein synthesis, cellular function, glucose use, hormone metabolism, immunity, and wound healing (Vallee and Falchuk 1993). Low zinc is prevalent (22–25%) in endurance athletes (Deuster et. al.,1989).***Chromium*** is a provisionally essential mineral that functions broadly in the regulation of glucose, lipid, and protein metabolism by potentiating the action of insulin at the cellular level. Athletes excrete higher amounts of chromium (Anderson et. al., 1988), which may result in increased nutritional needs. Monitoring micronutrient levels may help athletes to identify or recognize deficiencies and increase nutritional needs early to reduce the potential performance-impairing impact of nutritional deficiencies.

Food Allergies

One additional aspect of nutritional and metabolic health that may have value in athletes is that of an athlete's unique responses to certain foods. Blood-based biomarkers are available for testing food allergen sensitization that may or may not be known to the athlete. Adverse or unpleasant reactions (food allergy/intolerance) to particular foods may result from immunoglobulin E (IgE)-mediated mechanisms, where IgE is produced against specific food components in food-allergic individuals (Ebo and Stevens 2001). Immunoglobulin E (IgE) triggers immune responses within minutes to hours after consuming the food by way of mast cell degranulation resulting in the release of vasoactive and pro-inflammatory mediators. Allergies to peanuts, tree nuts (walnut, hazel, cashew, pistachio, Brazil nut, pine nut, almond), fish, shellfish (shrimp, crab, lobster, oyster, scallops), fruits, vegetables, seeds (cotton, sesame, psyllium, mustard), milk, egg and spices are most prevalent in adults (Ebo and Stevens 2001). Allergic reactions vary from aggravation of the skin, nose, eyes, lungs, and gastrointestinal tract to severe cardiovascular effects. Symptoms of allergic reactions may be noticed as swelling, inflammation, tenderness, redness and itching, burning of the lips, tongue, or palate, abdominal pain and cramping, nausea, vomiting, diarrhea, respiratory challenges, and asthma. Whereas a variety of methods be present to assess food allergies, immunoglobulin E (IgE) - based testing is considered an acceptable approach to assess suspected food allergies. Immunoglobulin E–based blood tests measure IgE directed against specific antigens, where levels can predict reactions to certain foods with greater than 95% certainty (Siles and Hsieh 2011). Specific IgE levels higher than 0.35 $kU.L^{-1}$ suggest sensitization (Siles and Hsieh 2011).The accurate recognition of causative foods is important for creating effective treatment plans for allergies in athletes, especially when pharmaceutical interventions are subject to the World Anti- Doping Agency (WADA) regulations. Testing of food allergen may be performed under resting conditions as part of athletes' preseason physical testing. Identification of potential food allergens is particularly important due to a condition known as food dependent exercise-induced anaphylaxis (Morita et. al., 2007). In this condition, exercise in combination with ingestion of the food agent triggers the allergic response (Morita et. al., 2007), possibly because of altered absorption from the gastrointestinal tract (Morita et. al., 2007), or altered IgE levels from exercise (Aldred et.al., 2010), or hyperosmolar conditions (Nielsen et. al., 1992). While the direct effects of IgE-mediated responses on exercise tolerance and performance are yet to be examined, symptoms like anaphylaxis, eosinophilic inflammation, bronchial hyperresponsiveness, urticariaangioedema, dermatitis, rhinitis or asthma, and gastrointestinal disorders (oral allergy syndrome, colic, nausea, vomiting, diarrhea, abdominal pain) may present a barrier to exercise tolerance.

Conclusion

The present review will help sport scientists, coaches, trainers, clinical sport professionals, researchers, and athletes to better understand how to monitor biomarkers of nutrition, metabolic health and food allergies of athletes, as they can better evaluate performance, modify training and identify nutritional deficiencies that elicit maximal improvements in athlete’s performance.

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