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ORIGINAL COMMUNICATION

The implication of the binomial nutrition-immunity on sportswomen's health

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The diet of many athletes is inadequate due to overly restrictive habits and an obsession with losing weight in order to maintain a particular level of body weight. Many female athletes, particularly those who participate in sports that emphasize leanness (gymnastics, distance running, diving, figure skating and classical ballet), have suboptimal energy and nutrient intakes and are at risk of compromised nutritional status, including fatigue, dehydration, nutrient inadequacies, delayed growth and an impaired immunocompetence. It is very well known that active women and girls who are driven to excel in sports may develop the so-called female athlete triad in which malnutrition, amenorrhoea and osteoporosis appear as typical signs of medical complications, frequently linked to serious psychological alterations. This outcome is mainly related to that found in eating disorders — syndromes in which athletes have been defined to be at increased risk. As a consequence of all these alterations, the immune system may be affected in athletes, and subsequently they might be more prone to infections. As there is a lack of knowledge about how the immune system may be affected in basal conditions of athletes, the study of immunocompetence as an index of the nutritional status is reviewed. In summary, it is necessary to encourage all professionals surrounding athletes to be aware of the importance of taking care of their nutritional status in order not only to avoid physical and psychological complications but also to improve performance and, thus, to achieve sporting goals.
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Risks for sportswomen nutritional status

Athletes as a group have special nutritional needs based on their age, sex, body composition and, most importantly, on the type, intensity, frequency and duration of activity required for their sport. The nutritional intake of elite athletes is a critical determinant of their athletic performance and ability to compete both physically and mentally (American Dietetic Association, 2000).

However, in response to the frequent pressure to lose weight that sportswomen are submitted to, they may practice unhealthy weight-control methods, ranging from restricted food intake (<1200 kcal/day), to self-induced vomiting, consumption of appetite suppressants and diet pills, or use of diuretics and laxatives (Sundgot-Borgen, 1996).

In fact, many female athletes, particularly those who participate in sports that emphasize leanness (gymnastics, distance running, diving, figure skating and classical ballet), have suboptimal energy and nutrient intakes and are at risk of compromised nutritional status (Sundgot-Borgen, 1996; Beals & Manore, 1998).

Young female elite gymnasts may face difficult choices in trying to deal with weight maintenance and optimal body-fat levels that are required when physiological demands are highest. In fact, the female athlete, driven to excel in her sport or pressured to have a thin physique, may attempt to lose body weight or body fat by developing uncontrolled patterns of disordered eating. This aberrant behaviour may lead to menstrual dysfunction and subsequent osteoporosis. These three distinct, but interrelated conditions are well-known as the female athlete triad (West, 1998).

Eating disorders in sports

Sports-related expectations combined with an obsessive focus on weight and food intake may set the stage for a serious risk of suffering from eating disorders (Sundgot-Borgen, 1996; Beals & Manore, 1998). Athletes at increased risk for eating disorders include those in endurance sports

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that favour participants with a low body weight, weight-classification sports, sports in which performance is subjectively scored, or appearance sports — in general those athletes who train for sports in which body contour-revealing clothing is worn for competition (West, 1998).

Disordered eating may impair athletic and work performance, and increase the risk of injury. Decreased caloric intake, and resulting fluid and electrolyte imbalances, can result in decreased endurance, strength, reaction time, speed and ability to concentrate (West, 1998).

Physical training duration and intensity contribute to athletic amenorrhoea. Exercise-induced amenorrhoea is now recognized as a multifactorial disorder in which several factors collectively suppress reproductive function. Amenorrhoea is just a symptom associated with low body weight, low body fat, physical stress, low energy and nutrient intake, energy drain and chronic hormonal alterations (Dueck *et al*, 1996; Marcos *et al*, 1998; West, 1998).

For this reason it is important to highlight the fact that young female athletes need to be educated about the negative health implications of menstrual disturbances. Contrary to popular belief, menstrual irregularities do not indicate optimal body fat or training levels. While cessation of menstruation may be viewed by some as convenient, it can be detrimental to bone health and may have long-term consequences resulting in infertility and other reproductive problems, impaired immune function, and an increased risk for cardiovascular diseases (Dueck *et al*, 1996).

Sports and immunity

Exercise induced changes occur in both the innate and adaptive components of the immune system (Nieman, 1998). Both acute exercise of varying severity and corresponding levels of long-term competition and training have been found to affect various components of the immune system including lymphocyte subsets, immunoglobulin levels, the mononuclear phagocytic system, polimorphonuclear leukocytes and cytokines (Eliakim *et al*, 1997).

The immune response to exercise is multifaceted, depending upon the type of exercise and the intensity of effort relative to the individual's state of training. It is important to know not only how exercise affects the various components of the immune system, but also what level of exercise is clinically beneficial or deleterious for the individual (Hoffman-Goetz & Pedersen, 1994).

Proportional to the degree of physiological stress encountered, changes in metabolism, hormone secretion, as well as other parameters will occur. In particular, exercise-induced elevations in plasma catecholamines and corticosteroids are of interest, because these substances have been shown to be immunoregulatory (Brenner *et al*, 1994).

Although many immune functions are stimulated by moderate physical activity and following long-term regular training, more vigorous effort and periods of heavy training suppress various immune response parameters, particularly if the physical activity is accompanied by environmental or competitive stress (Nehlsen-Cannarella, 1998). During this time, the so called 'open window' produces a decreased host protection and there is an increased risk of subclinical and clinical infection. The most frequent infection is the upper respiratory tract infection (URTI). There is also some evidence that immunocompetent cells are less effective in triggering defence mechanisms against infection after such exercise (Nieman, 1997,1998).

It has been proposed that the relationship between exercise and URTI may be modelled in the form of a J-curve. This model suggests that, although the risk of URTI may decrease below that of a sedentary individual when one engages in moderate exercise training, risk may rise above average during periods of excessive amounts of high-intensity exercise (Nieman, 1997).

For elite athletes who may be undergoing heavy exercise stress in preparation for competition, several precautions may help them reduce their risk of URTI. Considerable evidence indicates that two other environmental factors — improper nutrition and psychological stress — can compound the negative influence that heavy exertion has on the immune system (Nehlsen-Cannnarella, 1998). Thus, trying to provide, at least, adequate nutrition to these athletes may help to reduce some of these risks.

Immunocompetence as an index of the nutritional status in sport health

Most of the research works that have been published report the consequences of strenuous training and competitions on the immune system of athletes through time course assessments after the exercise bout, taking pre-exercise tests as control values. However, there is a lack of knowledge about the immune system status of trained individuals in basal conditions of exercise in relation to healthy individuals of the same age (Nova *et al*, 2001).

High-level and intense training, together with a low energy intake, seem to be responsible for the altered immunocompetence, particularly the cell-mediated immunity (Chandra, 1999), which may reflect the seriously compromised nutritional status of some athletes (Nova *et al*, 2001).

Immunocompetent cells

In previous studies, we have pointed out that, under basal conditions of exercise, leukocyte, lymphocyte and T-lymphocyte subset counts (CD2, CD3, CD4, CD8) were lower in a group of 10 gymnasts than in controls; this outcome may suggest that elite gymnasts could be at risk of malnutrition (López-Varela *et al*, 2000). However, acute exercise has been reported to induce an increase of peripheral venous leukocyte counts roughly proportional to the intensity and duration of physical activity. However, if physical activity is prolonged, leukocyte counts may decrease before the exer-

cise is terminated, possibly because the cells are migrating into injured muscle (Shephard & Shek, 1996).

Although we have detected normal levels of natural killer (NK) cells in elite gymnasts at basal conditions (López-Varela *et al*, 2000), both CD16 cell numbers and NK cell cytotoxicity have been found to rise during exercise followed by a decrease in NK cell number and function in the post-exercise period (Eliakim *et al*, 1997). The exercise-induced enhancement of NK cell activity could be mainly due to a redistribution of recirculating NK cells into the blood, which therefore may influence the percentage of NK-cells.

Cytokines

Cytokine production is altered in highly trained elite gymnasts in basal conditions reflecting a particular status of their immunocompetence that could be affected by the intensity and regularity of their exercise, the hormonal changes, stressful life conditions and very impaired nutrient intakes (Figure 1). It is generally accepted that high volume/intensity training, with insufficient rest, will produce muscle and/or skeletal and/or joint trauma. Circulating monocytes are then activated by injury-related cytokines, and in turn produce large quantities of proinflammatory IL-1β, and/or IL-6, and/or TNF-α, producing systemic inflammation (Suzuki *et al*, 2000).

In previous studies we have found higher IL-1β and IFN-γ secretion together with lower IL-2 production by *in vitro* stimulated blood mononuclear cells from gymnasts in comparison with controls, with no differences in IL-6 and TNF-α values between both groups. The differences found in IL-2, IL-1β and IFN-γ production between gymnasts and controls show that immunocompetent cells, obtained from trained subjects before any exercise has been practised in the day, respond differently to mitogen stimulation than cells from healthy sedentary subjects. It is probable that gymnasts could be under an adapted situation to both their long daily period of training and their restricted diets (lower than 1300 kcal/day). Thus, the measurement of immunocompetence at rest could reflect an adaptation mechanism to the particular physiological demands in the situation of these sportswomen (Nova *et al*, 2001).

Comparisons with eating disorder situation

There have been reported similarities between malnutrition status in elite gymnasts and patients with anorexia nervosa (AN) (Marcos *et al*, 1998). In fact, it has been pointed out that several mechanisms which involve hormone alterations and are developed in eating disorders are displayed to save energy, get adapted to deficient intakes, and maintain physiological functions within the normal range (Marcos *et al*, 1997,2001). Moreover, in individuals under excessive training, hormone alterations are involved in the mechanisms affecting immunocompetence (Smith, 2000). It is generally admitted that athletes are competitive, train at very high levels with inadequate rest, consume too few calories, avoid fat, and may be at increased risk of infections (Venkatraman *et al*, 2001). As already shown, it seems that some abnormalities in immunocompetent cell number and function are found in athletes undergoing regular training, even before daily exercise practice. This has probably a multifactorial cause which includes at least their continuous activity, their dietary habits, hormone alterations, and the competition-related stress (Nova *et al*, 2001). All of these characteristics

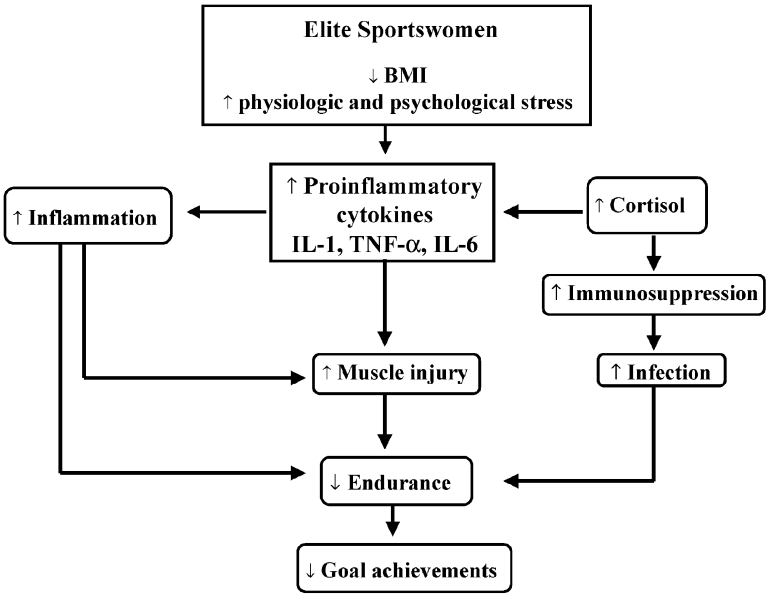

Figure 1 Severe consequences of low calorie intake together with physiologic and psychological stress on muscle, endurance and goal achievements in sportswomen.

Table 1 Comparative features of the immunocompetence between sportswomen and patients with anorexia nervosa

	Sportswomen	*Patients with anorexia nervosa*
Leucocytes	↓	↓
Lymphocytes	↓	↓
T-cells	↓	↓
B-cells	=	=
CD56	=	↓
Immunoglobulines (G,A,M)	=	=
IFN-γ	↑	↓=
IL-2	=↓	=↓
IL-1β	↑	↓=↑
IL-6	↑=	↓=
TNF-α	=↑	↓=

are not different from those found in patients meeting diagnostic criteria for an eating disorder such as AN or bulemia nervosa (BN), except that these patients may feel competition stress linked to many different social aspects that are not necessarily related to sport. Thus, the consequences of these shared particular conditions may lead to the presence of some similarities in immune cell abnormalities found in AN patients and sportswomen (Table 1).

Final remarks

All sports require a lot of effort by people practising them. However, sportswomen are particularly submitted to very stressful conditions, which lead them to develop situations of malnutrition that may be very similar to those observed in eating disorders. This outcome is linked to damaged immunocompetence, which hence increases their susceptibility to infections, limiting their expectation of attaining goals. In summary, we consider that it is necessary to highlight that all professionals around athletes should be aware of the importance of taking care of the nutritional status of this population group in order not only to avoid medical complications (some of them showing a psychic origin), but also to improve their performance and, thus, to achieve their sporting goals.

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