The Physiology of Women

Author: Helen Lenskyj (CAN)

Introduction

The article presented in this section has been condensed from a well researched and extensively referenced report titled "Women, Sport and Physical Activity" prepared by the author with the support of the Ministry of State, Fitness and Amateur Sport, Canada.

The FISA CDP recognises the fact that in many countries there has been an increase in the participation of women at all levels of sport. Unfortunately, this growth has not been supported by documentation to assist administrators and, particularly, coaches to recognise and work with specific physiological considerations related to women.

Although it is not possible to deal with every aspect of physiology pertinent to women's sporting performance, this section will present and discuss several topics to dispel some myths and provide practical assistance. This information should ensure that women are given an equal opportunity to improve their performance capabilities.

Physical Activity and General Health

Most of the health benefits of regular physical activity are common to both males and females: maintenance of optimal body weight and composition, prevention of coronary heart disease (CHD) and improved fat and carbohydrate metabolism. In fact, CHD, obesity, anxiety, low back pain and other conditions have been called the diseases of hypokinesis (inactivity). Since there is evidence that women lead more sedentary lives than men, there are special implications for women's health.

Although the incidence of CHD is higher for men than women, rates among women are rising, with high blood cholesterol levels, high blood pressure and cigarette smoking, particularly in combination with the use of oral contraceptives, constituting major risk factors. But, it should be noted that there is evidence of an association between improved physical fitness and a lowering of CHD risk factors in women. As well as having lower blood cholesterol levels, it has been shown that physically active women, specifically distance runners, tennis players and rowers, develop higher levels of high density lipoprotein, a major factor in protecting against CHD. Other health benefits of exercise include lowered blood pressure and improved fat and carbohydrate metabolism.

Physical Activity over the Adult Life Cycle

While it is commonly assumed that physical performance declines with age, it is possible that the decrease in regular physical activity found in both sexes over the life cycle is a more important factor than actual physical degeneration. There is ample evidence that women who engage in lifelong sufficiently intense levels of physical activity experience significant physiological benefits, including increased aerobic capacity, greater flexibility, reduced blood pressure and recovery time and lowered incidence of osteoporosis. Further, although it is difficult to separate physiological from psychosocial effects, there are numerous psychological studies which report enhanced self-worth and self-image associated with women's physical activity.

Physical Activity and Age-Related Osteoporosis

Genetic, mechanical, hormonal and dietary factors have been found to act together on the skeleton in retarding or accelerating osteoporosis (bone porosity characterised by reduced bone mineral content). While genetic factors may account in part for this pattern, it is also possible that variations are due to cultural differences in physical activity levels or to quantitative differences in muscle mass.

Physical activity stimulates bone growth and bone remodelling: increased bone density has been found in athletes, specifically in those bones subjected to stress in a specific sport. It is necessary to distinguish between cortical bone (as found in the tibia, for example) and trabecular bone (found in the spine). It is only cortical bone growth that is stimulated by physical activity. In non-athletes, the first signs of porosity are found in cortical bone which is not regularly subjected to mechanical stress during movement. There is evidence that exercise is effective in the prevention and treatment of osteoporosis, by contributing to the building of maximum bone mass before age 35 and to its maintenance during the rest of the life cycle.

Estrogen loss which occurs at menopause was thought to be a primary factor in age-related osteoporosis, but this does not explain the onset of bone loss before age 40 found in both sexes. Thus while estrogen deficiency is a factor in the increased rate of bone loss after menopause, it is not the basic cause.

Further, it has been reported that a conditioning programme can control the menopausal symptoms of vasomotor instability and depression for most women and that dietary calcium in conjunction with regular exercise has been recommended for prevention and treatment of bone loss, especially after menopause when estrogen loss may produce an imbalance in calcium absorption and excretion.

Physical Activity and Nutrition

General nutritional principles regarding energy, protein, vitamins, minerals and water apply to physically active individuals of both sexes. Other nutritional requirements specific to women are generally associated with the reproductive function, specifically, menstruation, pregnancy and lactation. As well, nutritional forms of prevention and treatment have been recommended for the pre-menstrual syndrome, osteoporosis and secondary amenorrhoea.

Blood loss through menstruation is a factor in the high incidence of iron deficiency found in the female population. Other factors include low dietary iron intake and reduced absorption of iron caused by dietary inhibitors (coffee, eggs, bran and other foods). **There are three stages of iron deficiency, all of which can affect physical performance: iron depletion, iron deficiency without anaemia, and iron deficiency anaemia.** At stage one, low serum ferritin concentration indicates depleted iron stores. Stage two is indicated by low levels of serum iron concentration and transferrin saturation and by increased levels of iron-binding capacity. Stage three, iron deficiency anaemia, is indicated by low haemoglobin concentration and other hemotologic data. **There is some evidence that female athletes are more susceptible to stage one deficiency than sedentary women, and pre-season testing of iron status through a battery of tests is recommended, since stages one and two cannot be detected through hemotologic data alone.**

Iron supplements are recommended for pregnant women and for those in whom iron deficiency or anaemia has been confirmed. The pregnant or lactating woman who maintains a regular programme of physical activity has nutritional needs above those of a nonpregnant athlete, in regard to her intake of calories, protein, iron, calcium and certain other minerals and vitamins.

Physical Activity and Weight Control

There is evidence that regular physical activity, in combination with caloric restriction, will bring about weight loss. However, even in the absence of changes in body weight, there are other important beneficial results of exercise for overweight individuals: increased lean body mass (fat-free tissue), decreased plasma insulin, improved glucose tolerance, reduction in blood lipids, decreased blood pressure and improved cardiovascular efficiency. It should be noted that improvements in fat/lean ratio are not necessarily accompanied by weight loss, since increases in muscle mass may offset decreases in body fat. Further, and perhaps more importantly, in the case of overweight women, regular exercise promotes physical fitness and psychological well being.

Body Composition and Skeletal System

Females as a group have a higher percent body fat than males. The two major classifications of fat are essential fat and storage fat. Essential fat is required for normal physiologic functioning and is stored in bone marrow, muscles and organs. Storage fat includes the fatty tissue that protects internal organs and subcutaneous fat. Sex-specific fat, thought to be associated with female hormone synthesis, is classified as an essential fat. The sex difference in body fat of approximately 9% is also found between male and female athletes within a particular sport. In addition to sex and sport, ethnicity and age have been identified as key variables in fatness and fat patterning among athletes. There is, however, a wide variation for both sexes across all sports. For example, female and male field event athletes have 23.9% and 15.6% respectively - levels that are close to the average non-athlete - while the figures for distance runners are 15.7% and 5%.

The high body fat levels in female swimmers aid in buoyancy and thermoregulation (regulation of body temperature), especially in open-water distance swimming. At the other extreme, the low body fat level of female distance runners is an important factor in any sport which requires moving the body through space. Thus, body composition may play a part in determining suitability for particular sports, and conversely, participation in these sports may contribute to developing and maintaining a certain body fat level.

The same relationship applies to somatotype. A particular type of physique may be a factor in the selection of a sport, and participation in that sport may influence body type, for example, by increasing muscularity or by retarding menarche so that the limbs grow longer during the extended growth period. **In females, ossification -** the hardening of the bones **- begins and ends from one to three years earlier than in males.** Since this process ends at puberty, late-maturing girls achieve greater height and longer limbs than those who mature early, while females, on average, tend to have smaller, shorter skeletal systems than males.

Research on body composition has tended to focus on high performance athletes. Even in this elite group, there are many exceptions to the general trend; thus, there are often highly successful individuals whose physiques and fat levels differ from what is considered ideal for their sport. **Therefore, the general relationship between body composition and suitability for particular sports need not be interpreted as a deterrent to participation for women with different physiques: body composition is only one of many factors contributing to athletic competence.**

Performance Capacity

Anaerobic/Aerobic Energy Systems

Three interrelated systems provide energy to muscles: two are anaerobic (oxygen-free) and one is aerobic (oxygen-utilising). Short term energy requirements (up to about 10 seconds), as in explosive events such as sprints and jumps, are provided for by the breakdown of phosphates stored in the muscles. Stair-running tests, which measure the ability to use phosphate stores in the leg muscles, show little difference between males and females when values are expressed relative to body weight. There are the expected differences based on intensity of training and type of sport: the most highly trained female athletes, and those in sports which require optimal leg power, produce the best performances on stair-running tests.

Medium term energy requirements (approximately 30 seconds to two minutes) are met by the lactic acid system. Glycogen stored in the muscles is partially broken down, producing lactic acid and adenosine triphosphate (ATP). Lower levels of lactic acid have been found after prolonged exercise in women than in men, indicating that less energy was available to them, but some past studies may have given female subjects lower workloads than males. Both sedentary women and trained female athletes respond to high intensity training regimens, showing improved anaerobic threshold as well as gain in anaerobic power.

The third system, the aerobic or oxygen system, uses glycogen and fat as energy sources and is important for activities performed at a submaximal rate over a lengthy period. Major factors involved in oxygen uptake include the oxygen carrying capacity of the blood (dependent primarily on haemoglobin concentration), cardiac output (related to heart volume and heart rate) and cellular utilisation of oxygen (arterial-venous oxygen difference). Up to puberty, sex differences in these areas are minimal. After puberty, sex differences in lean body mass and percent body fat are, to a certain extent, reflected in differences in the efficiency of the aerobic system, although environmental as well as physiological factors contribute to these differences.

Maximum oxygen uptake, or $V0_2$ max, is the usual measure of cardiovascular fitness and maximal aerobic power. It can be expressed in absolute terms or relative to body weight or to lean body mass. For athletes competing in the same sport, the differences between males and females average 51.5%, 18.6% and 9% respectively. **Differences in body size and composition have been found to account for most of the sex difference between male and female athletes in the same sport.** Although some basic biological differences in cardiac output, oxygen-carrying capacity of blood and muscle mass in males and females might be expected to produce about 10% difference, Nordic skiers have shown a sex difference of only 4% to 5%.

Thus, it cannot be said with certainty that any sex difference in $V0_2$ max is biologically determined. The physical demands of a specific sport, and not the sex of participants, constitute the major determinant of $V0_2$ max in athletes. Males and females in the same sport are closer in $V0_2$ max than females in different sports.

Training Responses

Research has shown that women demonstrate the same training response and percent improvement as men when they train at sufficiently intense levels. Therefore, women are able to achieve their full physical potential provided they are not restrained by a variety of social-cultural reasons.

Muscular Strength and Endurance

Muscle fibres may be designated as slow-twitch (ST) or fast-twitch (FT) depending on their composition and metabolic potential: ST fibre is suited to prolonged aerobic exercise and FT fibre to explosive power. Thus, individuals (of either sex) with a higher percentage of ST fibres are predisposed to greater success in endurance activities. Since ST/FT ratio is determined by heredity, it does not change with training although training increases the size of fibre area. There are no significant sex differences in the ST/FT ratio for athletes in the same sport.

There are sex differences in the size of fibre area and these are reflected in differences in the strength of males and females. However, if values for specific areas of the body are expressed relative to body size or lean body mass, sex differences are greatly reduced, especially in terms of leg strength. Overall, muscles form a lower proportion of a female's body weight than a male's. **Muscular flexibility is greater in females, compensating in part for their overall lower levels of muscular strength.** The relation of muscle strength to muscle cross-sectional area is the same for both sexes.

Strength training programmes have been shown to produce higher rates of strength improvement (up to 50%) in females than males, probably because females were initially further from their strength potential. Strength increases in women are accompanied by slight increases in muscle girth, especially in the arms and shoulders. With the lower levels of the growth-promoting hormone testosterone in females than in males, women will probably not experience the marked increase in muscle girth seen in men who engage in strength training programmes.

Flexibility

Flexibility of muscles, tendons and ligaments is related to more efficient sporting performance: for example, longer running strides, better hurdling techniques and better kick and arm movements in swimming. Females of every age group are more flexible than males. Greater flexibility of the joints and cartilage of the vertebral column, pelvic girdle and foot make women better adapted to springing, landing and extensions. The smaller tendons and ligaments, on average, in females may account for the greater mobility of some joints.

The most common flexibility test is the sit and reach, which measures trunk flexion and hamstring flexibility. Girls show continuous improvement from ages 10 to 18, with a gradual decline throughout the adult years. Although flexibility is increasingly recognised as both an integral component of physical fitness and an important factor in injury prevention, it is perhaps significant that some fitness surveys fail to include it. The emphasis on the "swifter, higher, stronger" ethos in male competitive sport is reflected in the attention paid to those measures of physical fitness which have clear and direct links to sporting performance, that is, measures of speed, strength and endurance.

Thermoregulation

Temperature regulation in females during exercise in hot environments is related to such factors as sweating rate, ratio of skin surface area to weight, body water content and metabolic rate. A review of studies investigating thermoregulation in males and females found more similarities than differences between the sexes and reported that some of the earlier research did not take into account the athletes' fitness levels, degrees of heat acclimatisation and exercise intensity. Overall, response to heat stress was found to depend more on the state of the cardiovascular system than on sex: training lowers the thresholds for sweating and vasodilation.

When men and women exercised at the same relative intensity, in hot, dry environments, there were few differences, while in hot, humid conditions, women's higher skin surface area/weight ratio facilitated heat loss and gave them greater heat tolerance. Menstrual cycle phase has little effect on thermoregulation, nor has aging been found to decrease sweating capacity.

Injuries

Sport medicine literature over the past decade supports the claim that most injuries are sport specific, not sex-specific. Thus, American-style football, for example, produces head, neck and upper body injuries, whereas gymnastics is associated with knee, ankle and foot injuries. This does not mean that football players, being male, have weak necks, or that gymnasts, being female, have weak ankles, although this kind of faulty reasoning is often seen in discussion of female athletes' injuries. In considering sport specific injuries, it is useful to identify three categories: injuries which result from overuse, from biomechanical fault or from collision with players or equipment.

It is difficult to determine the extent, if any, to which inherent characteristics (for example, biomechanical faults) are responsible for existing injury patterns among females. If girls were encouraged to develop their full physical potential from birth, and if their coaches and trainers were fully informed regarding the best methods of conditioning and injury prevention, present injury patterns among female athletes might change dramatically.

When comparisons are made for the same sporting activity, there are conflicting results: some studies of injury patterns in track athletes and basketball players show minimal sex differences; some report a greater incidence of knee, ankle and foot injuries among females; others report a higher overall injury rate for males.

On the issue of childhood injury, recent studies have shown that both sexes sustain serious injuries in school athletic programmes and in school playgrounds, again pointing to the importance of proper coaching, training and supervision for school-age children, male and female.

Virtually every discussion of women's sport-related injuries mentions the breasts. However, there is no evidence that female breasts are more susceptible to injury than any other part of the human body. Furthermore, the alleged causal relationship between trauma and breast cancer is not supported in the literature. Blows, punches or kicks to the breast sustained in contact/combat sports may produce bruises and, in extreme cases, a hard and sometimes painful lump may form in the fatty tissue (fat necrosis). Therefore, the wearing of chest protection is probably advisable, especially in martial arts. Depending on individual preference and physique, extra breast support may be helpful in increasing comfort during physical activity.