

## 3.2 Women's sport

### Introduction

Women were denied participation in ancient Olympic Games, as well as in the first modern Olympics. Their first participation, albeit testimonial, was in 1900. At the 1928 Olympic Games in Amsterdam, female participation became widespread and constituted 10% of the total number of participants. In the 1936 Berlin games, there were female participants from 20 countries; however, they were excluded from some events that were considered too tough and inappropriate for women. In the following years women gained ground, and in the Olympic Games of 2012 all participating countries fielded at least one female athlete. In the last Olympic Games, 45% of the 12,000 participating athletes were women. With the passage of time, and the increase in sports participation, women's records are constantly improving. Although women's performance has been increasing, in many disciplines their records are still below those of their male counterparts. This is, in part, due to the female physical and physiological characteristics. When working with female athletes, it is essential to know these differences, as well as a series of characteristic and unique factors that can influence their performance, health, injuries and recovery.

### Female physiology and hormones

Anatomically and physiologically, the female reproductive system can be considered to be constituted by three basic elements: the hypothalamus, the pituitary gland and the ovaries, which at the functional level constitute the hypothalamic-pituitary-gonadal axis. The hypothalamus produces and secretes the gonadotropin-releasing hormone (or GnRH), which determines the release of specific hormones from the anterior pituitary: the gonadotropins (LH and FSH), which act directly on the ovaries, and also indirectly, via feedback mechanisms. GnRH secretion isn't constant – it is pulsatile, and is controlled by feedback from the gonadotropins. FSH stimulates the growth of the ovarian follicle taking it through the different degrees of maturation. It stimulates the formation of FSH and LH receptors at the ovary level.

In the follicular phase, LH, combined with FSH, stimulates follicle development and is responsible for estrogen secretion. The significant increase in LH causes follicular rupture and ovulation, inducing the formation and maintenance of the yellow body. It is also responsible for estrogen and progesterone secretion.

The ovary has different functions: folliculogenesis, ovulation and hormonogenesis. Although the reproductive and endocrine functions are independent, they are intimately related. The ovary ensures the regular production of healthy oocytes and the regulation of the hypothalamic-pituitary axis, which is fundamental for regulating ovarian function, the determination of sexual characteristics, etc. The ovaries synthesize and secrete different steroid hormones:

- **Estrogens:** are derived from androgens. The main forms of estrogens are estrone, estradiol and estriol. They are essential for the regulation of the menstrual cycle. Estrogens increase osteoblastic activity and produce early fusion of the epiphysis (the end part or head of a bone) with the diaphysis (the central part of a bone). They slightly increase protein synthesis and determine the characteristic fat deposit. Estradiol is essential for gonadotropins to exert their actions on the ovary. Ovarian estrogens control the secretion of FSH and LH through actions at the level of the hypothalamic-pituitary axis.
- **Progestogens:** progesterone is the main human progestogen, and its main source is the corpus luteum during the second phase of the cycle. It acts on the endometrium and prepares it for gestation. During the luteal phase, the frequency of the pulsatile LH secretion decreases and stimulates FSH release. It has a slightly thermogenic action.
- **Inhibin:** acts on hypophyseal gonadotropins, inhibiting the production of FSH.
- **Activin:** this hormone stimulates the production of FSH. It acts inversely to inhibin.

The functional level of the hypothalamic-pituitary-gonadal axis' varies throughout life. Four phases can be distinguished: fetal, prepubescent, reproductive and menopause. The cyclicity of normal ovarian function during the reproductive stage is well known. The duration of the menstrual cycle is approximately 28 days (21 to 35 days) during the years of reproductive activity. The first day of menstrual bleeding is considered the first day of the cycle. The cycle is divided into the following phases:

- **Menstruation or regression phase:** lasts between 4 and 5 days, during which the endometrium flakes and menstrual flow occurs. This happens three days after the beginning of the luteolytic process and it is caused by steroid secretion from the corpus luteum in regression. The decrease in estradiol and progesterone induces an increase in the concentration of endometrial prostaglandins that produces vasoconstriction, endothelial injury and endometrial necrosis.

- **Proliferative, preovulatory or follicular phase:** lasts about 10 days and prepares the uterus and the endometrium for the fertilization of the ovule. The ovarian follicles secrete estrogens. This phase ends with ovulation.
- **Ovulatory phase:** normally happens between days 13 and 15. The preovulatory follicle secretes large amounts of estrogen, which exert positive feedback on the hypothalamic-pituitary axis, which produces the ovulatory secretion of LH and FSH. After the ovulatory release of gonadotropins, ovulation and luteinization occurs.
- **Secretory or luteal phase:** lasts between 10 and 14 days, during which the endometrium continues to increase thickness and the uterus prepares for gestation. The corpus luteum secretes progesterone, in addition to estradiol. Maximum progesterone production is reached by day 21 (early luteal phase) and is maintained until day 25 (mid luteal phase). During the late luteal phase, secretion gradually decreases until menstruation occurs. Pulsatile GnRH secretion is required for proper LH and FSH secretion.

## Neuroendocrine integration of the ovarian function

The hypothalamus controls and integrates the nervous and humoral signals from the central nervous system, the pituitary gland, the ovary and the uterus. It produces and secretes gonadotropin-releasing hormone (GnRH), which controls pituitary function. GnRH secretion occurs in pulses and determines the typical secretion of LH/FSH pulses. LH and FSH secretion is the ovarian function's main regulating factor. Ovarian steroids control gonadotropin secretion via a negative feedback mechanism.

## The menstrual cycle and performance

Alterations in athletic performance during the different phases of the cycle are subject to considerable individual variation. Some women don't experience any change in their performance and some have even achieved world records during menstruation, but others present considerable difficulties in the pre-menstruation phase or during menstruation.

But there have been few well-designed and controlled studies. Findings obtained in existing studies have created confusion regarding the different phases of the menstrual cycle. Some claim that athletic performance reaches its peak during the period immediately after menstruation, until the fifteenth day of the cycle. Others, however, claim that performance improves during

the menstruation phase. There seems to be no consensus on women's capacity to obtain better results during any specific phase of the cycle.

Nevertheless, premenstrual syndrome or dysmenorrhoea is likely to have a negative impact on women's athletic performance.

As stated above, there are physiological differences between men and women. It is very important to know them in order to understand them and obtain better performance results, as well as to develop better prevention tools for sports-related pathologies in women. These differences can be found in body composition, metabolic rate, calcium and iron metabolism, the size of organs and systems, as well as in the age of maturation.

Other changes, such as pregnancy and menstruation also modify the response. Psychological and sociological factors must also be added.

## **Growth and maturation**

Puberty begins earlier in women, between ages 10 and 13, as opposed to men, who reach puberty between the ages of 12 and 15. Differences in body composition occur after the onset of puberty, mainly due to endocrine changes. In men, testosterone secretion produces an increase in protein anabolism in the bone, the muscles, and in other parts of the body. In women, ovarian development and estrogen secretion begins when a sufficient quantity of gonadotropins has been secreted by the pituitary gland. Estrogens produce the characteristic changes in women: body growth, pelvic width, breast size, and fat deposits, especially in hips and thighs. They also stimulate longitudinal bone growth, allowing the bones to reach their final length between two and four years after the onset of puberty.

Women grow very quickly during the first years, and then cease to grow. Men have a slower and longer growth phase, which results in greater weight (17%) and body size (10%) than women. Estrogens increase adipose tissue deposition, in contrast to androgens, which increase fat-free tissue and muscle mass. These differences are partly responsible for increased differences in performance.

During puberty, the changes occur at the anthropometric level. Shoulder development increases in men, hip development increases in women. Their smaller shoulder size results in lower strength development in the upper extremities. Greater hip width increases the femoral angle, resulting in a lower center of gravity, which gives women an advantage in activities that require balance. Women show higher basal flexibility

## **Body Composition**

### **Basic Physical Differences**

### **Size and Body Composition**

Until puberty, there are no significant differences in body composition between men and women. Between the ages of 12 and 13, lean body mass and height tend to stabilize in women. In the case of men, on the contrary, lean body mass and height increase until approximately age 20. Women's maximum lean body mass is 72% of that obtained by men. Most of the women's muscle mass is below the waist.

Changes after puberty are mainly caused by endocrine changes. During puberty, the pituitary gland begins to secrete sufficient quantities of FSH and LH, which act on the estrogen secretion of the ovaries. Estrogens influence pelvic development, stimulate breast development and gradually increase the fat deposits in the thighs and hips. They also increase bone growth rate, which is why women grow rapidly for a few years after puberty, and then stabilize.

Because of these physiological differences, compared to men, women:

- are shorter;
- have less total weight;
- have less lean weight;
- have more fat weight.

### **Strength**

Due to the fact that they have less muscle mass than men, women have less capacity to generate strength. However, when strength is expressed in relation to lean mass, these strength differences disappear.

### **Cardiovascular and respiratory function**

Women have smaller hearts and less blood volume. At the same effort intensity, trained women generally have similar minute volumes to men, but with higher heart rates and lower stroke volumes. Respiratory responses differ due to the differences in body size. Women tend to reach the highest VO<sub>2</sub>max (maximum oxygen consumption) between ages 12 and 15. After puberty, their VO<sub>2</sub>max reaches between 70% and 75% of the average total VO<sub>2</sub>max for men. These differences may be due to the amount of extra body fat that women have and, to a lesser extent, to lower hemoglobin levels.

Regarding the anaerobic threshold, there are few or no differences between both sexes.

## **Physiological response to exercise**

Due to their hormonal differences training women tend to gain less lean body mass than men. Women can benefit from strength training, although strength gains are usually not accompanied by large increases in muscle volume. No strength differences were found when comparing corresponding cross muscle area units. It has been found that women can increase their strength between 20% and 40% with strength training. These gains are possibly due more to neural factors than to an increase in muscle mass. The cardiovascular and respiratory changes that accompany endurance training do not seem to be gender-specific. Women experience the same relative VO<sub>2</sub>max increases as men.

## **Female athlete triad**

At the beginning of the 1990s, a link was identified between inadequate diet, secondary amenorrhea and bone mineral disorders in female athletes. This link, which was first described in 1993 by the American College of Sports Medicine, was called Female Athlete Triad (FAT). With the increase in female participation in sports, the triad's incidence has increased, although it is not exclusive to the athletic population. The concept of the triad's components, as it was understood in the nineties, has changed. Currently, each component is considered to be a point in a continuous spectrum, rather than a strict assessment criterion:

-Energy availability: the range from optimal energy availability to low energy availability, with or without an eating disorder.

- Menstrual function: the range from "eumenorrhea" to "functional hypothalamic amenorrhea".
- Bone mineral density: the range from "optimal bone health" to "osteoporosis".

This makes it possible to identify more women who present any of the components, resulting in better prevention and better treatment. The triad's components are interrelated, and low energy availability is the basis for developing the others. This produces a hormonal dysfunction characterized by a suppression of metabolic and sexual hormones, mainly estrogens, which in turn suppresses bone formation and increases resorption. Total

recovery from the triad isn't possible without correcting this key component. Next, we will briefly describe each component.

## **Energy availability**

Female athletes have unique energetic and metabolic characteristics. Professionals who work with women athletes need to monitor and control their energy and nutrient intake, because it is necessary to ensure an adequate energy supply that satisfies not only their athletic and daily needs, but also their reproductive needs. It is also essential to keep young and teenage girls' extra energy needs in mind to ensure their proper growth and development. The main purpose is to prevent any health problem related to low or inadequate intake, because low energy consumption increases the risk of injury and disease, and also affects athletic performance.

Energy needs depend on many factors, mainly body composition and the type of athletic activity. There are, however, many women who don't satisfy their energy needs due to restrictions – intentional or unintentional – that aim to improve performance or change body composition by reducing body fat. Even though the methods for evaluating energy availability, dietary intake and energy expenditure are improving, they are still imprecise.

Energy availability is defined as the energy intake (kcal) minus the energy expenditure through exercise (kcal), divided by the kilograms of fat-free mass (FFM) or lean body mass. Under experimental conditions, this index has been significantly associated with changes in reproductive and metabolic hormone concentrations, as well as bone formation and resorption markers in women who reduce energy intake and increase energy expenditure through exercise. It has also been shown that the increase in exercise, while covering energy expenditure by increasing caloric intake, does not result in the interruption of LH pulsatility.

This research has helped to identify the threshold below which harmful physiological changes occur in reproductive and bone health, as well as in the metabolism. This threshold is 30 kcal per kilogram of fat-free mass or lean body mass per day. For example, in the case of an athlete with an absolute weight of 60 kg, of which 45 kg are lean body mass, a minimum consumption of 1350 kcal per day is necessary (45 kg FFM x 30 kcal) in order to prevent harmful changes due to low energy intake. The value for optimum energy availability is > 45 kcal/kg/FFM/day.

When a woman's intake is lower than the energy expended through exercise, she is considered to have low energy availability. It is important to know that energy availability can change during the season due to changes in body composition, competitive demand or the athlete's wishes. For this

reason, the moment when the measurements are made is highly important. If intake is similar to expenditure, the resting metabolic rate can be suppressed, causing it to be lower than expected for that sex, body size and activity level. Intake should be measured as accurately as possible during 7 to 10 days, and during training and competition. It is also recommended to measure the resting metabolic rate and energy expenditure during exercise.

There are several ways to measure energy expenditure during exercise: measuring oxygen consumption, GPS, accelerometers, questionnaires, etc. Eating disorders include a series of behaviors ranging from the simple inability to eat enough food to compensate for energy expenditure to worrying about eating and a deep fear of gaining weight (typically expressed by measures such as dietary restrictions or the use of weight-loss pills, laxatives or diuretics).

## **Menstrual function**

Menstrual dysfunction range from eumenorrhea to amenorrhea, and can help to identify athletes who may have low estrogen levels but continue menstruating. It includes luteal suppression, anovulation, oligomenorrhea and primary and secondary amenorrheas. Menstrual dysfunction occurs when LH pulsatility is lost because energy intake does not cover the needs. Since menstrual dysfunction due to low energy availability is an exclusion diagnostic which requires a complete analysis to rule out pregnancy, the use of medication, endocrinological or gynecologic pathology, etc. The athlete's menstrual periods, menarche and hormonal treatments, etc., should be recorded.

## **Bone mineral density**

The triad's final component is bone health, which describes a continuum ranging from optimal bone health to osteoporosis and focuses on bone strength, which consists of bone mineral density (or bone mineral content) and bone quality. Peak bone mass occurs between the ages of 20 and 30, with a peak bone mineral content between the ages of 9 and 20. Menstruating women gain between 2% and 4% of bone mass per year, while women with amenorrhea tend to lose 2% of BMD (bone mass density) per year. Women who have the triad, or present one of its components, are more susceptible to multiple fractures in large and less affected bones (femoral neck, vertebrae and pelvis). This is why it is important to identify the athletes who may show signs of the triad in order to avoid these manifestations or complications. In our environment, dual-energy X-ray absorptiometry (DEXA) is used as a quantitative measurement of bone health. This method uses T and Z scores to diagnose osteopenia and

osteoporosis. Since most athletes have a higher BMD than their sedentary counterparts, the ACSM has issued a set of recommendations for the assessment of bone mineral density in athlete populations. A Z-score of 2 SD (Standard Deviation) below the mean is defined as “below the range expected for age” in the case of premenopausal women, and as “low bone density for chronological age” in the case of young and teenage girls. The ACSM defines “low BMD” as a Z-score between  $-1.0$  and  $-2.0$  in the presence of nutritional deficiencies, hypoestrogenism, stress fractures and/or other secondary clinical risk factors for fracture and “osteoporosis” as a Z-score  $\leq -2.0$  along with secondary clinical risk factors for fractures. Since most athletes already have a higher BMD than non-athletes, the ACSM also recommends examining any athlete with a BMD Z-score below  $-1.0$ , even if no fractures are present.

## **Sports and pregnancy**

More and more pregnant women wish to continue exercising during pregnancy (Kardel and Kase, 1998, Knuttgen and Emerson, 1974). Although the beneficial effects of exercise on general health during pregnancy are well known, the information is still limited. Pregnancy is the condition that causes the largest amount of physiological changes in a woman's body. These changes are important, because the correct course of gestation, fetal health (Carreras, Guiralt, Del Pozo, and Sostoa, 1995), birth and lactation (Ezcurdia, 2001) depends on them. How physical exercise can benefit or alter these changes is still being researched.

Current information shows that regular physical exercise of moderate intensity in healthy pregnant women is beneficial during pregnancy, delivery and postpartum, and poses no risks to the mother and the fetus (Barakat R, Pelaez M, Lopez C, Lucía A, Ruiz Jr 2013). These benefits can be seen at cardiovascular (Perales et al., 2012) and psychological level and improve quality of life (Claesson et al., 2012) and weight control (Barakat et al., 2013).

Although the long-term cardiovascular effects of the mother's physical activity during pregnancy on the fetus are unknown, higher levels of exercise during pregnancy appear to be associated with more physically active children (Millard et al., 2013). Exercise during pregnancy may also reduce the incidence of fetal macrosomia and gestational diabetes (Cordero et al., 2012; Tomic et al., 2013).

As for childbirth, there is a benefit to the musculature involved, as well as less pain and effort during labor. There are positive effects for vaginal deliveries, and cesarean sections and instrumented deliveries are reduced

(Da Silveira et al., 2012). During postpartum, training accelerates recovery and makes it more bearable for the mother.

Regardless of the pregnant woman's physical state, there are absolute and relative contraindications, so it is essential that she be physically examined before starting any physical activity, and that a follow-up schedule be carried out (American College of Obstetricians and Gynecologists, 2002). When prescribing physical activity, it is important to take its type, duration and intensity into account. It should also be related to the woman's exercise habits prior to pregnancy and her physical condition (Butler, 1996; Ezcurdia, 2001). Contact sports are discouraged, because of their high intensity and the risk of falling. As for intensity, moderate aerobic exercise has proven to be the most appropriate (Barakat, 2002). This kind of exercise improves the mother's physical state and poses no risk to gestation or the fetus (Mottola and Wolfe, 2000). The duration will depend on exercise type and intensity. As for frequency, we recommend regular activity that results in the expected improvement.

It is important to ensure proper calorie and nutrient intake during physical activity and during gestation. Any physical activity program for pregnant women should include strengthening of the pelvic floor. The effects of physical activity in pregnant women on maternal-fetal health and performance, however, need to be further analyzed.

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