# Module 3. Sports injuries in other populations

## Unit 3.1 Injuries Associated with Sports Practice in Pediatrics

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Sports injuries are those which occur as a result of physical activity oriented to competition or leisure. The incidence of these injuries is conditioned by intrinsic and extrinsic risk factors.

> Intrinsic factors can be determined by the genetics of the individual or by congenital or constitutional factors, lack of flexibility, balance and/or coordination, previous injuries, and conditions of weakness or muscle imbalance. These factors can also be conditioned by physiological and biomechanical features of the process of growth and development. The extrinsic risk factors occur due to particular demands of sport, environmental conditions, and changes such as training planning, coach, playing surface, footwear, etc. (Mónaco et al., 2018, p. 296).

The epidemiological profile of injuries is related to the sport that is practiced (Brotons Cuixart, Mónaco, Sevilla Mora, Guerra Balic & Calvo Terrades, 2013). The incidence of injuries increases with age and with competitive demand, with a maximum peak between the ages of 10 and 14 years in both males and females (Fridman, Fraser-Thomas, McFaull & Macpherson, 2013; Gottschalk & Andrish, 2011; Kouteres & Gregory, 2010; Lykissas, Eismann & Parikh, 2013; Mónaco, 2015; Smith, Chounthirath & Xiang, 2016). However, as regards the distribution According to gender, some Authors highlight a higher incidence in males, while others highlight it in females (Fridman et al., 2013; Gottschalk & Andrish, 2011; Lykissas et al., 2013). Many of these studies are based on cutoff designs conducted in emergency services, not in population-based studies. Therefore, a greater participation of the male sex or the choice of the chosen sport may condition the

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results. As well as a higher level of aggressiveness of the male sex in certain disciplines (Caine, Caine, & Maffulli, 2006; Lykissas et al., 2013; Fridman et al., 2013; Magrini, Dahab, & Heyworth, 2016). However, a higher prevalence of anterior cruciate ligament (ACL) injuries is clearly significant in the female sex, probably conditioned by hormonal and biomechanical factors (Wedderkopp, Kaltoft, Holm, & Froberg, 2013).

The main difference in the pediatric population compared to adults is the process of growth and development. At the bone level it is determined by the growth plates and by the secondary nuclei of ossification (apophysis) (Rosendahl & Strouse, 2016). This condition determines a more conservative and protectionist attitude during the treatment of athletes at this age. The translation of treatment protocols and return to competition from adults to children is inadvisable (Magrini et al., 2016).

**Sport injuries can be acute or due to overuse.**

Acute injuries are more frequent during competition and in lower extremities (ankle and knee) (Lykissas et al., 2013). This prevalence is conditioned because most sports require the predominant participation of the lower extremity. They include different clinical entities, such as sprains, muscle injuries, fractures, anterior cruciate ligament (ACL) injuries and concussion.

Joint sprain is the main cause of acute injuries, being the ankle the most frequent affected area (Lykissas et al., 2013; Monaco, 2015). Diagnosis is clinical and treatment requires relative immobilization and sometimes oral anti-inflammatory medicine. However, in the presence of a joint sprain or suspected ligament injury in pediatric age, a fissure fracture should be ruled out, since in young children the Ottawa rules (see below) may be less noticeable (Doherty C. et al., 2014) (Brotons Cuixart et al., 2013).

Muscle injuries are the second leading cause of injuries. Along with tendon injuries, these are more frequent during late adolescence (Monaco et al., 2014). The main symptom is pain of abrupt onset, which can be localized by the patient using their finger, and functional impotence during the contraction of the affected muscle.

> Hematoma is found in cases of total or partial rupture (grade 2-3) and crepitus in cases of chronic tendinopathy. Pain depends on the degree of severity of the injury. In mild cases, it may be absent when resting and appear when stretching. Evening pain in the metaphyseal area is often "considered" of growth and no apparent etiology is found, but should not be confused with nocturnal pain that awakens the child. This should always lead to think about an oncologic cause, although in post-puberty it can be associated to chronic tendinopathy. The anatomical-functional knowledge will guide us in the etiological and structural diagnosis. (Mónaco et al., 2018, p. 297).

Acute fractures are the fourth cause of injury (between 18 and 25%) and prevail in the upper limbs (in children under 16 years of age). The mechanism is generally due to fall or avulsion. Their management depends on the severity and skeletal maturity of the subject (De Inocencio, 2004; De Inocencio, Carro, Flores, Carpio, Mesa, & Marín, 2016; Randsborg

et al., 2013; Smith et al., 2016). "Fissure fractures, characteristic in the bone in formation, require special attention as they can condition the growth of the affected limb" (Mónaco et al., 2018, p. 297). Conditioned by skeletal immaturity, they are usually sport-specific (Rosendahl, and Strouse, 2016).

In elderly people, in the presence of forced flexion and valgus trauma, ACL injury can occur in the knee. It has a higher incidence in women with joint hyperlaxity, in the presence of genu valgum and in certain sports, such as soccer, handball or skiing. However, the same situation in prepubertal or skeletally immature patients may result in a fracture of the tibial spine (lateral intercondylar) rather than an ACL injury. This is due to incomplete ossification of the tibial spine during growth and relative bony weakness associated to the ligaments. These acute injuries are among the most severe to consider. The difference between one or the other clinical entity is given by skeletal maturity (McConkey, Bonasia, & Amendola, 2011; Randsborg et al., 2013; Stracciolini, Casciano, Friedman, Meehan, & Micheli, 2015). The examination may be similar to that of ACL (pain, immediate swelling, positive or unclear Lachman test) and require imaging studies for diagnostic confirmation.

Other severe injuries are head traumas. The interest of pediatric specialists has been increasing in the last years, given the increase in incidence.

> They are frequent in males and in contact sports (soccer, rugby, handball, boxing, martial arts). Some experts call it Concussion (CC) or concussion (Anglo-Saxon term), which is a type of minor head injury (Mild traumatic brain injury - TBI); a series of metabolic changes occur at the neuronal level. (Monaco et. al., 2018, p. 297). These changes are conditioned by a transient interruption of cerebral blood flow, which conditions a complex pathophysiological process in the brain (Maugans, Farley, Altaye, Leach, & Cecil, 2012).
>
> These changes are manifested as an alteration of the brain function that affects memory, orientation and/or cognitive function to varying degrees. It may be produced by direct contusion (head, face or neck) or by forces transmitted to the brain by deceleration or rotational mechanisms. Loss of consciousness occurs in only 8-19% of cases and no imaging studies are required for diagnosis. Symptoms may be physical, cognitive, emotional or sleep disturbances. (Monaco et al., 2018, p. 297).

Many of these symptoms are subtle and lead to underdiagnosis in this population. This is the reason for the increased interest in this entity within the medical community. The clinical picture is resolved spontaneously in 7-14 days, although in children it requires a longer recovery time, and some symptoms may persist for months or years. These cases should be monitored with the SCAT5, a specific evaluation and follow-up method for this pathology. (Davis GA et al., 2017) (Mónaco et al., 2018, p. 297).

It is not considered a diagnostic method, but a follow-up method. Treatment consists of rest until symptoms disappear, and return to competition requires specialist judgment, with a gradual progression of training. Concomitant psychological treatment is sometimes required (Ledoux et al., 2017). The first intervention will be performed on the playing field and, at the slightest suspicion, the player should be removed from the field and suspend all physical activity for a minimum of up to 24 hours, until resolution of symptoms or the specialist's assessment. This recommendation aims at avoiding the second impact syndrome, produced by the transitory interruption of cerebral blood flow and its possible consequences. For this purpose, the pocket concussion recognition tool will be used, preferably in the player's native language (Maugans et al., 2012; Rose, Weber, Collen, & Heyer, 2015; Nelson, Loman, LaRoche, Furger, & McCrea, 2017; McCrory et al., 2017). The present topic will be developed in another reading.

**Figure 1: Pocket Concussion Recognition Tool. Spanish language.**

**Herramienta de Bolsillo de Reconocimiento de la Conmoción cerebral (Pocket CONCUSSION RECOGNITION TOOL™)**

**Para ayudar a identificar una conmoción cerebral en niños, jóvenes y adultos**

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### IDENTIFICAR Y RETIRAR

Se debe sospechar una conmoción cerebral si se presenta uno o más de las siguientes pistas, signos, síntomas visibles o errores en preguntas para la memoria.

### 1. Pistas visibles de posible conmoción cerebral

Cualquiera de ellas o todas las siguientes pistas visibles pueden indicar una posible conmoción cerebral:

Pérdida del conocimiento o sensibilidad
Acostado inmóvil en el suelo/se levanta con lentitud
Inseguro sobre sus pies/problemas de equilibrio o se cae/descoordinado
Agarrarse o sostenerse la cabeza
Aturdido, en blanco o mirada perdida
Confuso/no consciente del partido o de los hechos

### 2. Signos y síntomas de una posible conmoción cerebral

La presencia de uno o más de los signos y síntomas que siguen puede sugerir una conmoción cerebral:

- Pérdida de conocimiento
- Espasmos o convulsión
- Problemas de equilibrio
- Nauseas o vómitos
- Somnolencia
- Más emotivo
- Irritable
- Tristeza
- Fatiga o pérdida de energía
- Nervioso o ansioso
- "No sentirse bien"
- Dificultad de concentración
- Dolor de cabeza
- Mareo
- Confusión
- Lentitud de movimientos
- "Presión en la cabeza"
- Visión borrosa
- Sensibilidad a la luz
- Amnesia
- Sentirse como "en la niebla"
- Dolor de cuello
- Sensibilidad al ruido
- Dificultades para recordar

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### 3. La función de memoria

La falta de contestación correcta a cualquiera de estas preguntas puede sugerir una conmoción cerebral.

*"¿En qué cancha estamos hoy?"*
*"¿Primer tiempo o segundo tiempo?"*
*"¿Quién fue el último en marcar puntos en este partido?"*
*"¿Contra qué equipo jugaron la semana pasada/el último partido?"*
*"¿Ganaron el último partido?"*

**Cualquier deportista con una sospecha de conmoción cerebral debe ser INMEDIATAMENTE RETIRADO DEL JUEGO y no debe retornar a la actividad mientras no haya sido evaluado por un médico. Los deportistas con una sospecha de conmoción cerebral no deben quedarse solos y no deben conducir vehículos.**

Se recomienda que, en todos los casos de sospecha de conmoción cerebral, el jugador sea trasladado a un profesional médico para que emita un diagnóstico y orientación así como decisiones de retorno al juego, aún cuando hayan desaparecido los síntomas.

**LUCES ROJAS**
**Si ALGUNO de los que siguen se comprobaran, el jugador debe ser inmediatamente retirado en forma segura del campo. Si no hubiera disponible un profesional médico acreditado, considere transportarlo en ambulancia para ser evaluado en forma urgente por un médico:**

- El deportista se queja de dolor en el cuello
- Aumento de confusión o irritabilidad
- Vómitos repetidos
- Espasmos o convulsión
- Debilidad o cosquilleo/ardor en brazos o piernas
- Estado de deterioro del conocimiento
- Dolor de cabeza fuerte o en aumento
- Inusual cambio de comportamiento
- Visión doble

### Recuerde:

- En todos los casos, se deben seguir los principios básicos de los primeros auxilios (peligro, respuesta, vía respiratoria, respiración, circulación).
- No intente mover al jugador (aparte de lo necesario para el apoyo a la vía respiratoria) a menos que esté entrenado para hacerlo.
- No le saque el casco (si tuviera) a menos que esté entrenado para hacerlo.

de McCrory et. al, Consensus Statement on Concussion in Sport. Br J Sports Med 47 (5), 2013

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Source: Adapted from http://bit.ly/2oKP4JT

**Figure 2: Pocket Concussion Recognition Tool. English language.**

Source: Taken from http://bit.ly/2oKP4JT

On the other hand, the relationship between the excess of volume and training intensity is one of the main conditioning factors in overuse injuries, which are more frequent than acute injuries because growth plays a key role (Magrini et al., 2016). These injuries present the highest prevalence in pediatric age (more than 50 %), since they mainly affect immature athletes (physically or emotionally). Such prevalence is conditioned by a group of factors, especially during the unique early specialization (Carter, and Micheli, 2011; Franklin, Weiss, 2012; Gregory, Kerr, & Parsons, 2016; Magrini et al., 2016; Mostafavifar, Best, &Myer, 2013; Myer, Lloyd, Brent, & Faigenbaum, 2013).

The most common are osteochondrosis (including apophysitis), as well as low back pain, patellofemoral syndrome, iliotibial band syndrome, periostitis/stress fractures and burnout syndrome, among others.

Peak height velocity (PHV) occurs concomitantly with "relative bone weakness" and greater absolute muscle strength. Factors that associated with a specific and repetitive sporting gesture facilitate the occurrence of injuries. For this reason, many pathologies are sport specific, such as Sever's disease and Osgood-Schlatter disease in soccer and athletics, little

league elbow in baseball, distal radius physio stress syndrome or spondylolysis/listhesis in gymnasts, as well as osteochondrosis of pelvic location in soccer.

Apophysitis is a type of osteochondrosis at the tendon-bone junction of the immature skeleton. It is the equivalent of adult enthesitis (insertional tendinopathy). The initial symptomatology is insidious pain or discomfort that worsens with PA and decreases with rest (except avulsion which is a "pull out" with sudden onset of symptoms). Severe cases may manifest constant pain affecting activities of daily life. Diagnosis is clinical and imaging studies such as plain radiography or magnetic resonance imaging are used only for differential diagnosis when other pathologies are suspected or to confirm cases of avulsion. It is also performed in the event of worsening or lack of clinical improvement after one week of treatment. Musculoskeletal ultrasound is much more sensitive for these pathologies, although the difficulty of access and the good prognosis of these disorders limit its use in primary care. (Mónaco et al., 2018, pp. 297-298).

Prevention is based on flexibility work from before the PHV, and a stabilizing work of the agonist-antagonist muscles, together with an adaptation and periodization of the training loads.

Low back pain occurs frequently in the pediatric age group (20-30%), although it is not always a reason for medical consultation. It is more prevalent during PHV or associated with Tight Hamstring Syndrome (THS). The transitional musculoskeletal imbalance characteristic of adolescents conditions this pathology. As a general rule, all low back pain during anterior flexion of the trunk points to a mechanical etiology or involvement of the anterior vertebral area (e.g., disc herniation) and pain during low back hyperextension to a facet syndrome. Several entities may be the etiological cause of the latter, but spondylolysis (isthmic fracture) should always be ruled out in young people. In such a case, low back radiographs (posterior and anterior, lateral and bilateral oblique) will confirm the diagnosis. (Mónaco et al., 2018, p. 298).

The treatment consists of sports rest or Boston Brace (MacDonald, Stuart, & Rodenberg, 2017; Patel, & Kinsella, 2017).

Patellofemoral syndrome (PFPS) is the most common cause of gonalgia in adolescents. Its etiology is uncertain, but it is characterized by an imbalance between agonist and antagonist muscles, and a stabilizing insufficiency of the structures adjacent to the patella. This conditions a misalignment of the femoro-patellar-tibial axis producing excessive

> friction during the maximum flexion-extension movement in areas not involved under usual conditions. (Mónaco et al., 2018, p. 298).

Retro or peripatellar pain is typical and sometimes there is articular cartilage involvement (Halabchi, Mazaheri, & Seif-Barghi, 2013; Kim, et al., 2016).

> This misalignment is associated with an increase in the Q angle, which is conditioned by the increase in the bitrochanteric diameter and that is why it is more frequent in women. It is characterized by a sensation of joint instability ("knee failure") after prolonged periods of sitting, pain when ascending or descending stairs and sometimes swelling. Palpation is painful at the patellar facet joint (or when moving it) and Zohlen's sign is positive but not pathognomonic. Knee radiographs require specific projections and guide the diagnosis. The treatment consists of physiotherapy and complete physical inactivity is contraindicated.
>
> Iliotibial Band Syndrome is less frequent than the pathologies described previously (prevalent in cyclists and in long-distance runners). It is characterized by pain and increased tension in the lateral part of the thigh (positive Ober test). When associated with gluteus medius weakness, running biomechanics may be altered (positive Trendelemburg maneuver). Palpation of the external femoral condyle during the knee flexion-extension mechanism (30-90 degrees) helps in the diagnosis. The treatment is physiotherapeutic.
>
> Periostitis is the inflammation of the periosteum as a consequence of a stress conditioned by multiple factors including biomechanical aspects (e.g. tibia vara or foot pronation), sudden changes in the intensity and/or duration of training, footwear or surface of the playing field. Although the tibial area is the most frequent, it is not the only area, and its finding is sport specific (common in long-distance runners). The clinical presentation is of pain of insidious onset, diffuse, in the 2/3 of the posteromedial tibia. It subsides with rest and worsens with PA. Palpation may detect some roughness and bone pain. These periostitis and its mechanism can evolve to a stress fracture, in which case the pain will be punctual and exquisite when the affected area is palpated. The diagnosis is clinical and radiological. The plain radiography visualizes a thickening of the periosteum (periostitis) and in the stress fracture there is a solution of continuity at the level of the bony cortex. Sometimes, a bone scan or magnetic resonance imaging (MRI) is required for diagnostic confirmation. However, MRI is more sensitive for early stages, reporting different degrees of stress or bone edema prior to fracture (Mónaco, et al., 2018, pp. 298-299).

Treatment consists of rest and biomechanical correction or orthosis (Cody O'dell et al., 2016; De Inocencio et al., 2016; Mónaco et al., 2018).

> Burnout syndrome occurs with a frequency of 30% in adolescent athletes. It is a response to chronic stress during which their participation or performance in an activity they previously enjoyed decreases. It usually manifests with a loss of physical performance of 2 months of evolution, with organic symptoms (severe), poor physiological adaptation to training and stress response not explained by any organic cause. It also manifests with psychological or social symptoms, which are non-specific and its diagnosis is based on a detailed clinical history to rule out organic causes (Table 3). Treatment consists of relative rest and modification of the triggering factors. Resolution time depends on the disappearance of symptoms, which in some cases may last weeks or months. (Mónaco et al., 2018, p. 299).

# Unit 3.2 Women's Sport

David Domínguez

## Introduction

Women were denied the right to participate in the Ancient Olympic Games as well as in the first modern ones. The first participation of women in the Olympic Games, although testimonial, was in 1900. In the 1928 Amsterdam Olympics, female participation was generalized and reached 10% of the total number of participants. In 1936, in Berlin, women's participation was extended to 20 countries; however, they were excluded from some trials that were considered too hard and unsuitable for women. In the following years, women gained ground, and it was at the 2012 Olympic Games that all participating countries had a woman among their athletes. In the last Olympic Games, women accounted for 45% of the 12,000 participating athletes. Over the years, in addition to the increase in sports participation, the records obtained by women are constantly improving. Even though women's performance has been increasing, their records still lag behind those of their male counterparts in many disciplines. This is partially due to female physical and physiological characteristics. When working with the female athlete population, it is critical to understand these differences as well as a number of unique and characteristic factors that can influence their performance, health, injuries and recovery.

## Review of Female Physiology and Hormones

Anatomically and physiologically, the female reproductive system can be considered to be made up of three basic elements: the hypothalamus, the pituitary gland and the ovaries, which functionally constitute the hypothalamus-pituitary-gonadal axis. The hypothalamus produces and secretes gonadotropin-releasing hormone (or GnRH), which determines the release of specific hormones from the adenohypophysis, the gonadotropins (LH and FSH) that act directly on the ovaries, and also indirectly, through feedback systems. GnRH secretion is not constant but pulsatile, and it is controlled by feedback from gonadotropins. FSH stimulates the growth and maturation of the ovarian follicle. It stimulates the formation of new receptors for FSH itself and then of receptors for LH at the ovarian level.

In the follicular phase, LH, together with FSH, stimulates follicle development and is responsible for the secretion of estrogen. The significant increase in LH generates follicular rupture and ovulation; it induces the formation of the yellow body and its maintenance. It is also responsible for the secretion of estrogen and progesterone by the estrogen.

The ovary performs different functions: folliculogenesis, ovulation and hormonogenesis. The reproductive and endocrine functions, although independent, are closely related. The ovary ensures the regular production of healthy oocytes and the regulation of the hypothalamic-pituitary axis, which is essential for the regulation of ovarian function, determination of sexual characteristics, etcetera. The ovaries synthesize and secrete different steroid hormones, which are:

- Estrogens: they are derived from androgens. The main ones are estrone, estradiol and estriol, which are essential for the regulation of the menstrual cycle. They increase osteoblastic activity and produce premature fusion of epiphyses (ends or heads of the bone) with the diaphysis (central area of the bone). They produce a slight increase in protein synthesis and determine the characteristic fat deposition. Estradiol is essential for gonadotropins to exert their actions on the ovary. Ovarian estrogens control FSH and LH secretion by their 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 pregnancy. During the luteal phase, it decreases the frequency of pulsatile LH secretion and stimulates FSH release. It has a slight thermogenic action.
- Inhibin. It acts on pituitary gonadotropins, inhibiting FSH production.
- Activin. This hormone stimulates FSH production, doing the opposite of the inhibin.

The level of functioning of the hypothalamic-pituitary-gonadal axis varies throughout life. Four phases can be distinguished: fetal, prepubertal, reproductive and menopausal. The cyclicity of normal ovarian function during the reproductive stage is well known. The length of the menstrual cycle during the reproductive years is approximately 28 days (21 to 35 days). 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:** it lasts 4 to 5 days during which the endometrium sheds and produces menstrual flow. It occurs three days after the onset of the luteolytic process and is caused by the secretion of steroids by the regression of the corpus luteum which is 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, pre-ovulatory or follicular phase:** it lasts about 10 days and prepares the uterus and endometrium for fertilization of the egg. Ovarian follicles secrete estrogens. This phase ends when ovulation occurs.
- **Ovulatory phase:** it normally occurs between days 13 and 15. The preovulatory follicle secretes large amounts of estrogens, which exert a positive feedback on the hypothalamic-pituitary axis, leading to ovulatory secretion of LH and FSH. Following ovulatory release of gonadotropins, ovulation and luteinization occur.
- **Secretory or luteal phase:** it lasts 10 to 14 days, during which the endometrium continues to thicken and the uterus prepares for pregnancy. The corpus luteum secretes progesterone in addition to estradiol. Maximum progesterone production is reached around day 21 (early luteal phase) and is maintained until day 25 (mid luteal phase). In the late luteal phase, secretion gradually decreases until menstruation occurs. For the proper secretion of LH and FSH, the pulsatile secretion of GnRH is necessary.

## Neuroendocrine Integration of Ovarian Function

The hypothalamus is the site of control and integration of nervous and humoral signals from the central nervous system, pituitary, ovary and uterus. The hypothalamus produces and secretes gonadotropin-releasing hormone (GnRH), which controls pituitary function. GnRH secretion occurs in the form of pulses and determines the typical LH/FSH pulse secretion. LH and FSH secretion is the main regulatory factor of ovarian function. Through a negative feedback mechanism, ovarian steroids control gonadotropin secretion.

## Menstrual Cycle and Performance

Alterations in sport performance during the different phases of the cycle are subject to considerable individual variation. There are women who experience no change in their performance; some have achieved world records during the menstrual phase, but others have considerable difficulties in phase previous menstruation or during it.

There are few well-designed and controlled studies. The ones that are available are confusing with respect to the data obtained for the different phases of the menstrual cycle. Some indicate that sport performance is at its best during the period immediately following menstruation up to the fifteenth day of the cycle. Nevertheless, there are others who indicate that performance improves during the menstrual phase. It seems that there is no general model regarding women's ability to perform better during any specific phase of the cycle.

However, premenstrual syndrome or dysmenorrhea is likely to negatively influence the performance of the woman who suffers from it.

As mentioned previously, there are physiological differences between men and women. It is very important to know them so as to understand them, obtain better results from the performance point of view and have better prevention tools for the pathology derived from sports practice in women. These differences can be found in body composition, metabolic rate, calcium and iron metabolism, the size of organs and the different systems, as well as differences in the age of maturation.

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

## Growth and Maturation

Puberty in girls begins earlier, between the ages of 10 and 13, as opposed to boys, which begin between the ages of 12 and 15. Differences in body composition occur after the onset of puberty, mainly due to endocrine changes. In the case of men, testosterone secretion produces an increase in muscle and skeletal protein anabolism, and in other parts of the body. In women, ovarian development and estrogen secretion begins when a sufficient amount of gonadotropins is secreted by the pituitary gland. Estrogens are the ones that produce the characteristic changes in women: body growth, pelvic width, breast size and fat depositions, especially in the hips and thighs. Moreover, they stimulate longitudinal growth of bone, which allows bones to reach their final length between two and four years after the onset of puberty.

Women grow very quickly in the early years, and then they stop growing. Men have a slower and longer growth phase, resulting in greater weight (17%) and body size (10%)

than women. Estrogens increase the adipose tissue, as opposed to androgens, which increase fat-free tissue and also increase muscle mass. These differences are responsible, in part, for the increased differences in performance.

Anthropometric changes occur during puberty. While men have an increase in the development of their shoulders, women experience this with their hips. The smaller the size of the shoulder is, the less strength development the upper extremities will have. When the width of the hips is greater, there is an increase in the femoral angle. This produces a lowering of the center of gravity, which gives an advantage in those activities that require balance. Women show higher baseline levels of flexibility.

**Body Composition**

**Basic Physical Differences**

**Body Size and Composition**

There are no major differences between males and females with respect to body composition until puberty. Between the ages of 12 and 13, lean mass and height tend to stabilize in women. This is not the case for men, in whom they continue to increase until approximately 20 years of age. The maximum lean mass achieved by women is 72% of that obtained by men. Most of the muscle mass in women is below the waist.

These changes that occur after puberty are mainly due to endocrine changes. During puberty, the pituitary gland begins to secrete sufficient amounts of FSH and LH that act on the ovaries for estrogen secretion. Estrogens influence the development of the pelvis, stimulate breast development and increase fat deposition in the thighs and hips. Estrogens also increase the rate of bone growth, so women grow quickly for a few years after puberty and then they stabilize.

Due to these physiological differences, women, with respect to men:

- are of a smaller size;
- have lower total weight;
- have lower lean weight;
- have a higher fat weight.

**Strength**

Due to the smaller amount of muscle compared to men, women have less capacity to build strength. However, when strength is expressed in relation to lean mass, the differences in strength disappear

**Cardiovascular and Respiratory Function**

Women have smaller hearts and lower blood volume. For the same intensity of effort, trained women generally have similar minute volumes to men at the expense of a higher heart rate and lower stroke volume. There are differences in respiratory responses, which are due to differences in body size. Women tend to reach the peak of their VO2 max (maximal oxygen uptake) between the ages of 12 and 15. After puberty, their VO2 max reaches 70-75% of the average male VO2 max. These differences could be explained by

the amount of extra body fat that women have and, to a lesser extent, by lower hemoglobin levels. As regards the anaerobic threshold, there is little or no difference between the two sexes.

### Physiological Responses to Exercise

With training, women generally gain less lean mass than men, due to hormonal differences. Women can benefit from strength training, although strength gains are generally not accompanied by large increases in muscle bulk. No differences in strength have been found when comparing equal cross muscle area units. With strength training, it has been found out that women can experience 20-40% strength gains. Probably, these gains are mostly due to neural factors than to increased muscle mass. The cardiovascular and respiratory changes that accompany endurance training do not seem to be sex-specific. Women experience the same relative increases in VO2 max as men.

### Female Athlete Triad

In the early 1990s, a combination was identified between inadequate nutrition, secondary amenorrhea and mineral and bone disorders in female athletes. This combination, which was first described in 1993 by the American College of Sports Medicine, was named the female athlete triad (TMD). With the increase in female participation in sports, the incidence of the triad has increased, although it is not exclusive to the sports population. The concept of the components of the triad, as understood in the 1990s, has changed. Each component is now considered to be a point on a continuum, rather than a severe assessment criterion:

- Energy availability: spectrum ranging from optimal energy availability to low energy availability with or without eating disorder.
- Menstrual function. Spectrum ranging from "eumenorrhea" to "functional hypothalamic amenorrhea".
- Bone mineral density. Spectrum ranging from "optimal bone health" to "osteoporosis".

This allows us to identify more women who may present any of the components in order to offer them better prevention and treatment. The components of the triad are interrelated and low energy availability is the pillar for the development of the others. This produces a hormonal dysfunction characterized by the suppression of metabolic and sexual hormones, mainly estrogens, which in turn produce the suppression of bone formation and increased bone resorption. Without the correction of this key component, full recovery of the triad will not be possible. Next, we will briefly describe each of the components.

### Energy Availability

Women who practice sports have unique energetic and metabolic characteristics. Professionals working with female athletes need to monitor and control the intake of energy and nutrients, since it is necessary to ensure an adequate energy intake to meet not only sports and daily life needs, but also reproductive needs. Moreover, for the proper growth and development of girls and adolescents, it is essential to keep in mind their extra energy needs. The main objective is to prevent any health problems related to low

or inadequate intakes, since low energy intake increases the risk of injury and illness, and also affects sports performance.

Energy needs vary according to many factors, mainly body composition and the sport practiced. However, many women do not meet their needs due to intentional or unintentional restrictions that seek to improve performance or modify body composition by decreasing body fat. Even though methods for assessing energy availability, dietary intake and energy expenditure are improving, they remain imprecise.

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

This research was helpful in identifying the threshold below which detrimental physiological changes in reproductive and bone health and metabolism. This threshold is 30 kcal per kilogram of fat-free mass or lean mass per day. For example, in the case of an athlete with an absolute weight of 60 kg, of which 45 kg are lean mass, a minimum intake of 1350 kcal per day (45 kg FFM (fat free mass) x 30 kcal) is necessary so that the detrimental changes resulting from low energy intake do not occur. The value considered for optimal energy availability is > 45 kcal / kg / FFM / day.

If women have an intake lower than the energy expenditure produced by exercise, they are considered to have low energy availability. It is important to know that energy availability may change during the season due to changes in body composition, competition demands or the athlete's wishes. Therefore, the moment at which the measurements are taken is critical. In the event that intake is similar to expenditure, there may be a suppression of the resting metabolic rate, causing it to be lower than expected for that sex, body size and activity level. Intake should be measured as accurately as possible between 7 and 10 days, and during training and competition. It is also advisable to measure resting metabolic rate and energy expenditure during exercise.

During exercise, energy expenditure can be measured using a variety of tools: measurement of oxygen consumption, GPS, accelerometers, questionnaires, etc. Eating disorders include a spectrum of behaviors ranging from a simple inability to eat enough food to compensate for energy expenditure to preoccupation with eating and a deep fear of gaining weight (typically expressed through measures such as food restrictions or the use of weight loss pills, laxatives or diuretics).

**Menstrual Function**

Menstrual dysfunction describes the spectrum from eumenorrhea to amenorrhea and allows the detection of a large proportion of female athletes who may have low estrogen levels but continue to menstruate. Menstrual dysfunction includes luteal suppression, anovulation, oligomenorrhea, and primary and secondary amenorrhea. Menstrual dysfunction occurs when LH pulsatility is lost, which happens when energy intake does not meet the needs. Since menstrual dysfunction caused by low energy availability is a diagnosis of exclusion, it is necessary to perform a complete study to rule out pregnancy,

use of medications, endocrinological or gynecological pathology, etcetera. It is necessary to have a record of the athlete's menstrual periods, as well as the menarche, the use of hormone treatment, etc.

**Bone Mineral Density**

The final component of the triad is bone health, which describes the continuum 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 years, with a maximum bone mineral content between the ages of 9 and 20 years. Menstruating women gain between 2% and 4% of bone mass per year, while amenorrheic women tend to lose 2% of BMD (bone mass density) per year. Women who have the triad, or any 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 athletes who present the triad so as to avoid these symptoms or complications. In our setting, dual-energy X-ray absorptiometry (DXA) is used as a quantitative measure of bone health. This method uses T and Z scores for the diagnosis of osteopenia and osteoporosis. Because most female athletes have higher BMD than their sedentary counterparts, the ACSM issued recommendations for bone mineral density assessment in the athletic population. Athletes with a Z-score 2 SD (Standard Deviation) below the average will be said to have low bone density below the expected range for age, if they are premenopausal women, and low bone density for chronological age, if they are adolescents and girls. The ACSM defined low BMD as a history of nutritional deficiencies, hypoestrogenism, stress fractures and/or other secondary clinical risk factors for fracture along with a BMD Z-score between -1.0 and -2.0 and osteoporosis as secondary clinical risk factors for fracture with a Z-score ← -2.0. Since most female athletes already have a higher BMD than non-athletes, the ACSM also recommends screening any athlete with a BMD Z-score below -1.0, even in the absence of fracture.

**Sports and Pregnancy**

More and more pregnant women want 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, information is still limited. Pregnancy is the condition that produces the most physiological changes in a woman's body. These changes are important, since the correct course of gestation, fetal health (Carreras, Guiralt, Del Pozo, and Sostoa, 1995), delivery and lactation depend on them (Ezcurdia, 2001). How these changes may be benefited or altered by physical exercise is under investigation.

The information we currently have shows that regular, moderate-intensity physical exercise in healthy pregnant women has benefits during gestation, delivery and postpartum, and does not involve risks to the mother and the fetus (Barakat R, Pelaez M, Lopez C, Lucia A, Ruiz Jr 2013). These benefits are observed at the cardiovascular (Perales et al., 2012) and psychological levels, and allow for a better quality of life (Claesson, et al., 2012) and better weight control (Barakat, et al., 2013).

Even though the long-term cardiovascular consequences to the fetus as a product of maternal physical activity during pregnancy are unknown, it seems that higher levels of exercise during pregnancy are associated with higher levels of physical activity in

offspring (Millard, et al., 2013). Pregnant women may also benefit from a lower incidence of fetal macrosomia and gestational diabetes (Cordero et al., 2012; Tomic et al., 2013).

In the case of childbirth, there is a benefit in the musculature involved as well as less pain and effort during labor. The benefits are positive with respect to vaginal deliveries, and cesarean sections and instrumented deliveries are reduced (Da Silveira et al., 2012). In the postpartum period, recovery occurs earlier and is more bearable for the mother because of the training.

Regardless of the physical condition of the pregnant woman who does physical exercise, there are absolute and relative contraindications so it is essential that, before starting the activity, there is a medical review to include the pregnant woman in any physical activity program as well as a strict follow-up (American College of Obstetricians and Gynecologists, 2002). When prescribing physical activity, it is important to consider the type, duration and intensity of physical activity. In addition, it is recommended that these aspects be related to the exercise habits prior to pregnancy and to the physical fitness of the pregnant woman (Butler, 1996; Ezcurdia, 2001). As regards intensity, moderate-intensity aerobic exercise has been shown to be the most appropriate (Barakat, 2002). This type of exercise produces improvements in the maternal physical condition without risk to the pregnancy or the fetus (Mottola and Wolfe, 2000). The duration will depend on the type of exercise and the intensity. Regarding the frequency, we should recommend a regular activity that allows to obtain the expected improvements.

It is important to ensure an adequate intake of calories and nutrients during physical activity and pregnancy. Any physical activity program for pregnant women should include pelvic floor strengthening. However, it is necessary to deepen in the results that the practice of physical activity in pregnant women has on maternal-fetal health and performance.

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