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# FROM GIRL TO WOMAN: BECOMING AN ADULT; PUBERTY, THE MENSTRUAL CYCLE AND THE EFFECTS ON PHYSICAL PERFORMANCE

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World Village of Women Sports

SISU Idrottsböcker

# FROM GIRL TO WOMAN: BECOMING AN ADULT; PUBERTY, THE MENSTRUAL CYCLE AND THE EFFECTS ON PHYSICAL PERFORMANCE


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## SUMMARY

This text examines the physical changes that occur during puberty, the effects of these changes on physical performance and, conversely, the effects of intense physical activity on normal pubertal development. The normal menstrual cycle and its influence on performance and sports-related injuries are also discussed.




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## TAKE HOME MESSAGES:

- Adolescence, which is defined as the period from the onset of puberty until adulthood, is characterised by dramatic changes in growth rate and sexual, psychological and social development. These changes can greatly affect physical performance and the motivation to engage in physical activity.
- Normal puberty is associated with increased aerobic and anaerobic power, as well as increased muscle strength.
- Hard physical training combined with insufficient energy intake may adversely affect the reproductive system, leading to a delay in pubertal development.
- Although delayed puberty often has no apparent long-term consequences, there may be a risk of lower peak bone mass, shorter final height than otherwise expected and increased risk of stress fractures.
- No pubertal signs by age 13 and no menstruation by age 16 should always be investigated.
- Some research suggests that the normal menstrual cycle may influence neuromuscular performance, balance and the incidence of musculoskeletal knee injuries.
- Oral contraceptives have no impact on physical performance in healthy athletes.

## PHYSICAL CHANGES DURING PUBERTY

Adolescence, which is defined as the period from the onset of puberty until adulthood, is characterised by dramatic changes in growth rate and sexual, psychological and social development. The first sign of the normal onset of puberty is an accelerated growth rate (Figure 1). On average, girls grow 25 cm during puberty, with the growth rate peaking about a year before the first menstruation (menarche). Menarche occurs at a mean age of just under 13 years for girls in the Western world, and occurs relatively late in the order of developmental changes during puberty. At menarche, most girls have reached 90 percent of their predicted final height. Thereafter, growth slows rapidly and the final height is reached less than two years after menarche. Girls with late onset of puberty have a longer growth period than do girls with early onset, while boys reach their target height about two years later than girls do.

**Pubertal stages, girls**

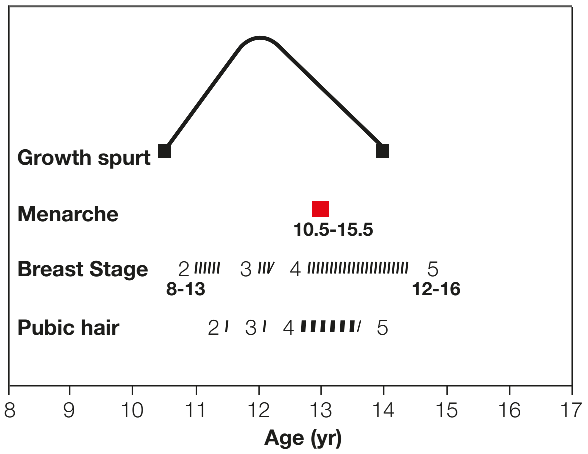


**Figure 1.** Timing of the changes during normal pubertal development in girls.

Breast development starts early in adolescence as breast budding (Figure 1). Pubic hair often appears a couple of months after the breast buds, while axillary (armpit) hair growth starts two years later. Normal development of the breasts and pubic hair often occurs concurrently and has been classified into different stages by Tanner (Figure 2). The development in most girls is complete by the age of 15.

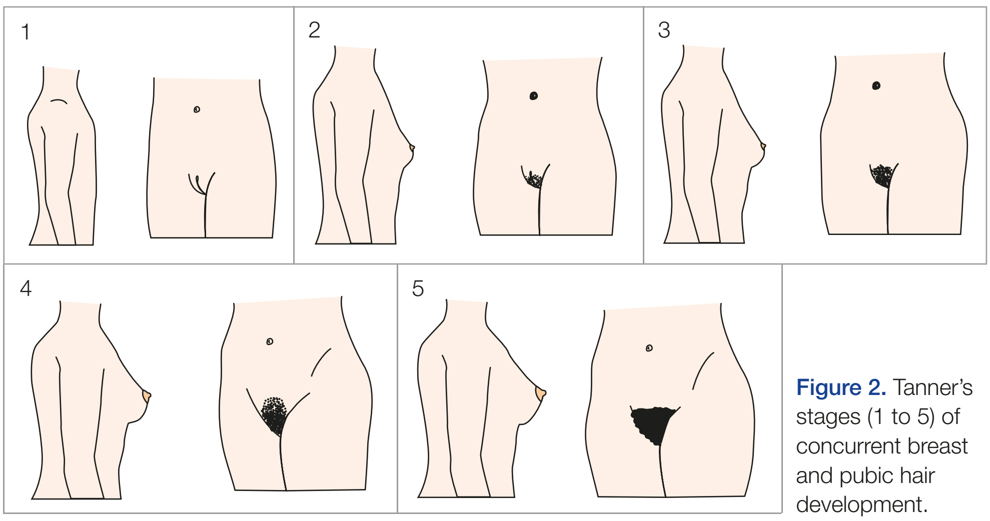


**Figure 2.** Tanner's stages (1 to 5) of concurrent breast and pubic hair development.

During puberty, girls increase their bodyweight and a change occurs in body composition: the amount of fat increases by an average of 11 kg, and its distribution changes towards a typical female type. By the end of puberty, girls have normally increased their proportion of bodyweight consisting of fat from 15 to 25 percent. In contrast, boys maintain a body fat proportion of 15–20 percent into adulthood and instead have a marked increase in muscle mass.

Bone maturation also occurs during puberty. Bone mineral density (BMD) increases as height increases; the rate of increase slows after menarche. Two to four years after menarche, spinal BMD has reached the adult level, although it can increase further up to age 20. In the hip, peak bone mass is reached somewhat later—around 16 years of age in girls—but also can continue to increase up to age 20. In adulthood, bone mass as a proportion of bodyweight is lower in women than in men.

## THE HORMONAL REGULATION OF PUBERTY

The first distinct hormonal change in pre-pubertal girls is the increased production of 'male' hormones (androgens) from the adrenal glands. These androgens stimulate the growth of body hair and activate the oil glands and the sweat glands in the skin. Pubertal development is then controlled by the gradually maturing reproductive system, under the control of the brain and the pituitary gland.[1] The endocrine (hormonal) changes start with an increased secretion of gonadotropin releasing hormone (GnRH) in the hypothalamus (a part of the midbrain). GnRH causes increased secretion of luteinizing hormone (LH) and follicle stimulating hormone (FSH) from the pituitary (Figure 3). The first LH pulses occur during sleep and gradually extend throughout the day. The rise of FSH and LH levels stimulates an increase in circulating oestradiol, which is produced by the ovaries. Breast development, female fat distribution and maturation of the reproductive tract occur as the level of oestradiol increases. Pubic and axillary hair growth and acne are caused by increased androgen secretion from the adrenal glands and the ovaries.

Growth hormone from the pituitary gland and oestradiol from the ovaries are necessary for the accelerated growth rate during puberty. The pubertal growth spurt is also associated with an increase in circulating levels of the important anabolic hormone, insulin-like growth factor-I (IGF-I). This growth factor is produced mainly in the liver under the influence of growth hormone (Figure 3). Oestrogens are also responsible for the epiphyseal closure[2] of the long bones that occurs in late puberty.

1 The *pituitary gland* is a small gland at the base of the brain that is physically connected to the part of the brain called the hypothalamus. It secretes hormones that act on the reproductive organs.

2 The *epiphyses* are the growth plates located near the ends of bones from which new bone is produced. When bone growth is complete, these cartilaginous plates are converted to bone, which is called *epiphyseal closure*.

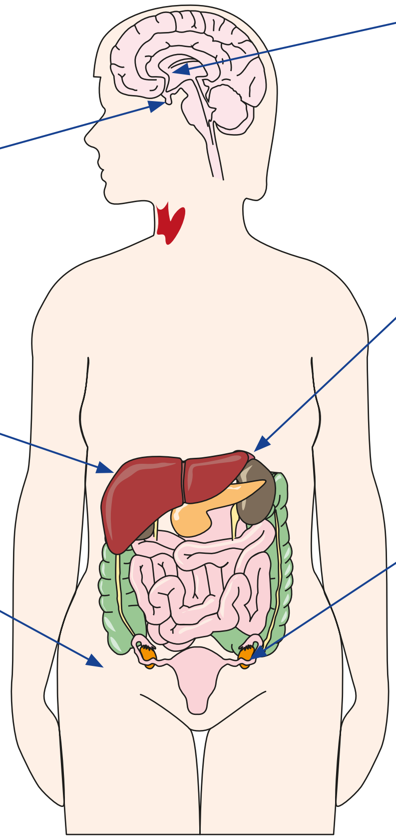


**Figure 3.** The endocrine organs and hormones involved in development during puberty.

Although the timing of puberty is primarily genetically determined, nutrition, physical health, and social and psychological factors also appear to influence its initiation and progression. The age at menarche of mothers and their daughters correlates quite well. Furthermore, it has been suggested that a critical percentage of body fat (17 %) must be reached to achieve menarche, but the specific figure is questionable. Leptin, which is a hormone secreted in proportion to the amount of body fat by the cells that store fat, has been implicated in pubertal development by acting on the hypothalamus (Figure 3). Girls who are moderately obese have earlier menarche than do girls of normal bodyweight. Conversely, girls with anorectic behaviour have delayed menarche. However, girls who are morbidly obese may also have delayed menarche, which indicates that other factors are also involved.

## PUBERTY AND PHYSICAL PERFORMANCE

Pubertal changes in growth rate, bodyweight and body composition can influence physical performance in different ways depending on the sporting discipline. For some sports such as alpine skiing and ice hockey, increased growth and body mass may be beneficial. And in swimming, an increase in body fat is usually not a disadvantage. Puberty is also associated with increases in aerobic power, anaerobic power and muscle strength, which should improve performance in several disciplines. However, in some sports such as endurance and aesthetic sports, where a lean body composition is regarded as an advantage for physical performance, increased bodyweight can impair performance. A girl whose performance suddenly deteriorates may find that both training and competition have lost their meaning and purpose. Thus, girls may lose interest in sport during adolescence. In this context, the sports leader has an important role in showing understanding of pubertal changes, and in supporting the girl throughout this phase of development. Impaired performance during puberty may eventually result in even better performance after puberty, and consequently in a more motivated sportsperson.

The beneficial effects of exercise during growth are well known, for example, increased bone mass; however, the reproductive system can be adversely affected by some types of exercise. High-intensity training at an early age tends to delay pubertal development, including growth and menarche. Prolonged hypothalamic inhibition of GnRH secretion has been suggested as the underlying cause. Delayed puberty in girls is defined as no pubertal signs by age 13, and delayed menarche as no menstruation by age 16. The incidence of delayed puberty differs between athletic disciplines, but delays are particularly common in gymnasts and ballet dancers. In these disciplines, a low body weight is of great importance for maximal performance.

Many factors other than high-intensity training are also associated with delayed puberty, such as a low amount of body fat, inadequate nutrition, eating disorders, genetic predisposition and psychological stress. Determining the role of inheritance in the delay of pubertal development in athletes can be difficult. Some studies suggest that a genetically dependent delay in sexual development and the genetic expression of desirable physique characteristics leads to a ‘selection phenomenon’, or bias towards selecting these individuals, which would artificially inflate the rate of pubertal delay seen in the particular discipline. However, a break from training due to, for example, injury often leads to a rapid catch-up in pubertal development, which indicates that environmental factors also play a part. In some cases, dieting and restrictive eating behaviour combined with hard physical training can seriously affect pubertal development, leading to delayed menarche, failure to reach peak bone mass, lower final height than otherwise expected and increased risk of stress fractures.

## MANAGEMENT OF DELAYED PUBERTY

Delayed puberty in a girl (no pubertal signs by age 13) and delayed menarche (no menstruation by age 16) should always be evaluated by a paediatrician or a gynaecologist. The usual workup includes hereditary factors, and a full history of growth development, timing of breast and pubic hair appearance, weight loss and diet, amount and intensity of training, and any other bodily abnormalities. Physical examination includes weight, height, and evaluation of breast and pubic hair development. A pelvic examination by abdominal ultrasound is performed to evaluate the internal reproductive organs. Bone age is evaluated by an x-ray of the wrist to determine potential growth. Laboratory tests include measuring the blood levels of hormones and nutritional factors such as vitamins. The most common hormonal pattern is reduced levels of LH and FSH, and low levels of oestradiol.

In the case of a constitutional delay of puberty, a ‘wait and see’ approach is often recommended, but sometimes it may be clinically relevant to induce puberty with low-dose oestrogen treatment. Mostly, however, delayed puberty in athletes is explained by inadequate nutrition in relation to energy expenditure. General recommendations are to optimise nutrient intake and to adjust the training volume and intensity. Supplementation of calcium and vitamin D may be beneficial for bone development. Failure to gain weight, or weight loss, may indicate an incipient eating disorder. Diagnosis of these disorders at an early stage is vital, and girls with a suspected eating disorder should be referred to a specialist clinic for professional care.

## THE MENSTRUAL CYCLE

The first cycles after menarche are usually irregular due to absence of ovulation (anovulation). This period of irregularity may last one or two years and is generally followed by normal ovulatory cycles.

A normal menstrual cycle varies between 21 and 35 days, but most women have a 4-week cycle. The menstrual cycle can be divided into three distinct phases (Figure 4): the follicular phase (from the onset of menses to ovulation), the ovulatory phase, and the luteal phase (after ovulation to the onset of the next menstrual bleeding). In women with ovulatory cycles, the follicular phase varies in duration (7–14 days) and accounts for the range of normal cycle lengths, whereas the luteal phase is relatively constant and averages 14 days in most women. The ovulatory phase is shortest and lasts 24–48 hours.

### The follicular phase

The first day of bleeding is referred to as Day 1 of the cycle and is the first day of the follicular phase. During the first days of the follicular phase, the levels of female sex hormones are low. Circulating concentrations of FSH secreted by the pituitary gland increase in the early follicular phase and reach maximum levels during the first half of the phase. During this period, FSH stimulates the growth and development of a group of follicles (containing developing ova, or eggs) in the ovaries. Usually, only one of the follicles will be selected to fully mature and ultimately rupture at the time of ovulation, releasing the ovum that is ready for fertilisation. Under the influence of FSH, the growing follicle starts to produce oestradiol, which significantly increases levels in the bloodstream by Day 7 of the cycle. Peak blood levels occur on the day before ovulation. Oestradiol is essential to mature the follicle and cause the endometrium (the lining of the uterus) to grow and thicken in preparation to receive a fertilised egg.

### The ovulatory phase

The rise in oestradiol stimulates LH secretion and reduces FSH secretion from the pituitary. At mid-cycle, the concentration of LH in the blood peaks (the ‘LH surge’), which induces ovulation about 12 hours later. The secretion of androgens such as testosterone by the ovary is stimulated by LH and peaks with the mid-cycle LH surge. This androgen production promotes degeneration of non-dominant follicles and stimulates libido. After the LH surge, oestradiol levels fall for several days.

### The luteal phase

After ovulation, the empty follicle in the ovary develops into another structure called the corpus luteum. During the luteal phase, LH stimulates the production of progesterone from the corpus luteum, which peaks mid-phase. Progesterone suppresses new follicular growth. Oestradiol is also secreted from the corpus luteum, with a secondary increase in oestradiol levels that peak in mid-phase. If the egg is not fertilised, the corpus luteum degenerates 10–12 days after formation and the production of female sex hormones declines. The withdrawal of oestradiol and progesterone initiates breakdown of the endometrium, which leads to the next menstruation.

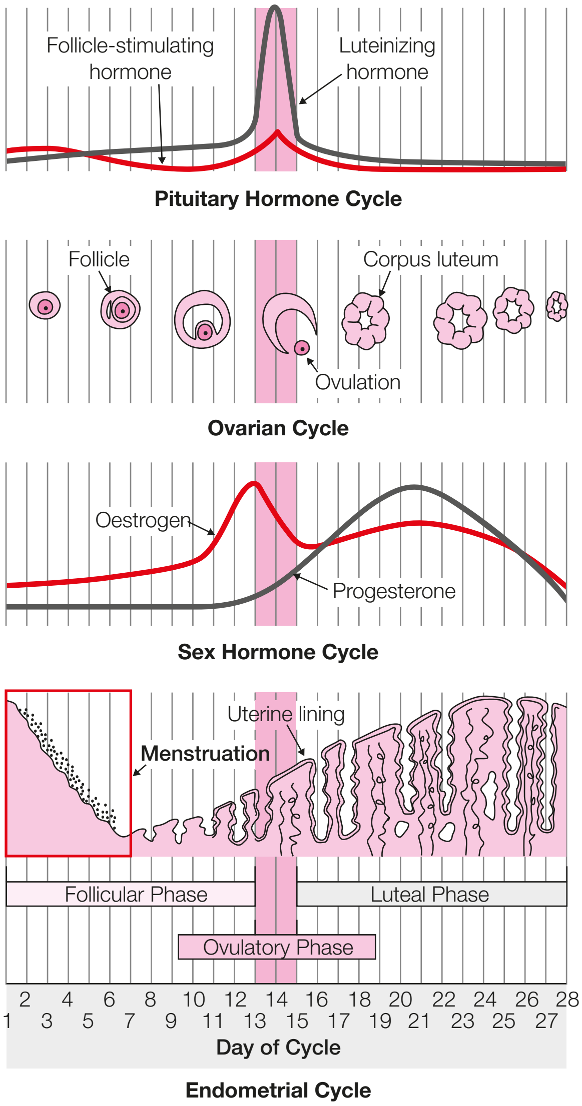


**Figure 4.** The menstrual cycle. The cycle is divided into three distinct phases: the follicular phase (from the onset of menses to ovulation), the ovulatory phase (from the LH surge to the time of ovulation), and the luteal phase (after ovulation to the onset of the next menstrual bleeding).

## INFLUENCE OF THE MENSTRUAL CYCLE ON PHYSICAL PERFORMANCE AND INJURY

Some studies indicate that the variation in female sex hormone levels during the menstrual cycle may affect physical performance and the risk of sustaining a musculoskeletal injury. In most studies, the follicular phase (when oestrogen dominates) has been compared with the luteal phase (when both oestrogen and progesterone are produced). However, many studies have failed to confirm the phases of the menstrual cycle by measuring hormonal levels, which may partly explain the varying results that have been reported.

Oestrogen may exert anabolic (muscle building) effects on skeletal muscle by increasing glucose uptake and glycogen storage. In contrast, progesterone might have catabolic effects on muscle metabolism (causing increased breakdown). However, evidence of the effect of the menstrual cycle on muscle strength is conflicting—increased, decreased and unchanged muscle strength have all been associated with high circulating levels of oestrogen. The most rigorous studies have shown no differences in muscle strength during different phases of the menstrual cycle.

The results of studies on the effect of the menstrual cycle on aerobic and anaerobic performance also differ. Several studies have shown increased minute ventilation during the luteal phase but not in the follicular phase. Researchers suggested that increased progesterone levels in the luteal phase influence chemoreceptors in the respiratory centre. Progesterone is also considered to increase body temperature by affecting temperature regulation in the brain. However, most studies have shown no influence of the menstrual cycle on maximal oxygen consumption ($VO_2max$), blood lactate or time to exhaustion (measures of aerobic and anaerobic performance). Nevertheless, hormonal fluctuations during the menstrual cycle might be useful for optimising training programs for female athletes, and this possibility should be explored in future studies.

Some studies have shown significant variations in knee joint laxity, neuromuscular coordination and postural control during the menstrual cycle. Increased knee joint laxity and improved neuromuscular coordination during the ovulatory phase (the time of highest oestradiol levels) have been reported. Additionally, impaired postural control (balance) has been demonstrated in the luteal phase (when both oestradiol and progesterone levels are high), particularly in women with premenstrual symptoms. Postural control is a complex function involving sensory receptors throughout the body, and the vestibular (the balance organ in the inner ear) and visual systems, as well as muscle activity. Although measurement of postural control has been used to identify subjects with increased risk of musculoskeletal injuries, any association remains controversial.

The mechanisms behind variation in neuromuscular function during the menstrual cycle are unknown. Fluctuations in oestradiol and progesterone levels might affect hormone receptors on tendons and ligaments, and thereby alter motor function. Central mechanisms affecting balance may also be involved.

The risk of sports injuries is higher in female athletes than in male athletes, particularly for injuries of the knee joint, such as damage to the anterior cruciate ligament. The underlying cause for this sex difference is unclear, but differences in anatomy, body composition, muscle strength, knee stiffness, and jumping and landing have been suggested. Hormonal factors have also been implicated, and an association between musculoskeletal knee injuries and the menstrual cycle has been reported. However, the results are inconsistent, because higher injury rates have been observed during both the premenstrual phase and the ovulatory phase. Other researchers have reported that women with premenstrual symptoms are at greater risk of injury than are women without these symptoms.

## ORAL CONTRACEPTIVE USE IN FEMALE ATHLETES

Oral contraceptives (OCs) containing both oestrogen and progestin are used by countless women for birth control, as well as for medical treatment of menstrual pain, heavy bleeding, endometriosis and menstrual disorders. OCs can also be used to postpone menstruation when desirable. The treatment is generally well tolerated and has few side effects. However, some women may experience side effects such as headache, swelling and weight gain, and the risk of venous thrombosis is slightly increased. Reports from the 1980s showed that OCs were not used as frequently by sportswomen as by women in the general population.

However, today the proportion of OC users appears similar among female athletes and non-athletes.

Despite this wide use of OCs by athletes, little is known about their effects on body composition and sports performance. No change in weight or body composition has been reported with OC use in regularly menstruating athletes. Furthermore, muscular strength and functional aerobic capacity are not influenced by OC use in regularly menstruating athletes. However, in athletes with menstrual disorders and oestrogen deficiency, OCs have been demonstrated to increase body fat, to normalise hormonal changes that reflect energy deficiency and to counteract loss of bone mass. OC treatment could therefore benefit these athletes. Despite body composition changes in athletes with menstrual disorders, OC treatment has showed only marginal impact on physical performance in these women. This information is important for sportswomen because there is a concern that OCs might impair physical performance.

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