



Formation of the Menstrual Cycle in Adolescent Girls and Hormonal Changes During Puberty

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Abstract

Puberty is a complex biological transition during which the child's body gradually acquires reproductive, endocrine, somatic, and psychosocial maturity. In adolescent girls, one of the most important markers of pubertal development is the onset and subsequent maturation of the menstrual cycle. Menarche, or the first menstrual bleeding, usually occurs after the activation of the hypothalamic–pituitary–gonadal axis and reflects the progressive interaction between the hypothalamus, pituitary gland, ovaries, uterus, and peripheral endocrine tissues. However, the establishment of regular ovulatory cycles does not occur immediately after menarche. During the first postmenarchal years, menstrual cycles are often irregular because the neuroendocrine mechanisms controlling gonadotropin-releasing hormone, luteinizing hormone, follicle-stimulating hormone, estrogen, and progesterone secretion are still maturing. This article discusses the physiological formation of the menstrual cycle in adolescent girls, the hormonal changes of puberty, normal and abnormal menstrual patterns, and the clinical importance of monitoring menstruation as an indicator of adolescent reproductive health.

Keywords: adolescence, puberty, menarche, menstrual cycle, estrogen, progesterone, hypothalamic–pituitary–gonadal axis, reproductive health, adolescent gynecology.

Introduction

Adolescence is a critical period of human development characterized by rapid physical growth, sexual maturation, hormonal reorganization, emotional changes, and the gradual formation of reproductive capacity. In girls, puberty is not a single event but a sequence of coordinated processes involving breast development, pubic and axillary hair growth, acceleration of linear growth, redistribution of body fat, maturation of the reproductive organs, and the appearance of menstruation. Puberty in females usually begins between 8 and 13 years of age, although individual variation is common and depends on genetic, nutritional, environmental, ethnic, and socioeconomic factors.

The menstrual cycle is one of the most visible indicators of female pubertal maturation. Menarche represents an important biological and social milestone, but it should not be understood as the immediate achievement of full reproductive maturity. In many adolescent girls, the first menstrual cycles are anovulatory and irregular because the hypothalamic–pituitary–ovarian axis requires time to develop stable cyclic activity. According to clinical guidance from the American College of Obstetricians and Gynecologists, menstrual cycles in adolescents commonly range from 21 to 45 days, and the mean cycle interval during the first gynecologic year is about 32.2 days.

Understanding the formation of the menstrual cycle during adolescence is clinically important for several reasons. First, normal menstrual variation must be distinguished from pathological menstrual disorders. Second, abnormal bleeding patterns may be early signs of endocrine disorders, coagulation defects, eating disorders, chronic disease, polycystic ovary syndrome, thyroid



dysfunction, or pregnancy-related conditions. Third, menstrual education helps adolescent girls understand their bodies, reduce anxiety, and seek timely medical care when necessary.

Materials and Methods

This article was prepared using a narrative review approach. Scientific and clinical information was analyzed from endocrinology, adolescent medicine, gynecology, and reproductive physiology sources. The main focus was placed on the physiology of puberty, maturation of the hypothalamic–pituitary–gonadal axis, hormonal regulation of the menstrual cycle, normal adolescent menstrual patterns, and common causes of menstrual irregularity.

The analysis included the following thematic areas: the endocrine basis of puberty, the sequence of female pubertal development, the role of gonadotropin-releasing hormone, follicle-stimulating hormone, luteinizing hormone, estrogen and progesterone, the maturation of ovulatory cycles, and clinical markers of normal and abnormal menstruation in adolescents. Special attention was paid to the interpretation of irregular menstrual cycles during the first years after menarche, because this is one of the most frequent concerns in adolescent gynecological practice.

Results

Pubertal development in girls begins with the reactivation of the hypothalamic–pituitary–gonadal axis. During childhood, this axis remains relatively suppressed. As puberty approaches, hypothalamic neurons begin to secrete gonadotropin-releasing hormone in a pulsatile manner. This pulsatile secretion stimulates the anterior pituitary gland to release follicle-stimulating hormone and luteinizing hormone. These gonadotropins act on the ovaries and promote follicular development, estrogen synthesis, and later progesterone production after ovulation. Pubertal activation is regulated by a complex neuroendocrine network involving kisspeptin, neurokinin B, dynorphin, and other central regulatory factors.

One of the earliest visible signs of puberty in girls is thelarche, or breast development. This process is mainly stimulated by rising estrogen levels. Pubarche, or the development of pubic hair, is influenced largely by adrenal androgens produced during adrenarche. Growth acceleration occurs as a result of interactions between sex steroids, growth hormone, insulin-like growth factor 1, and nutritional status. Menarche generally occurs later in the pubertal sequence, often after the peak height velocity has already been reached. Studies on determinants of menarche note that menarche is usually a relatively late pubertal event and is influenced by genetic and environmental factors.

The menstrual cycle is controlled by cyclic changes in ovarian and endometrial function. In a mature ovulatory cycle, the follicular phase begins with the recruitment of ovarian follicles under the influence of follicle-stimulating hormone. Growing follicles produce estrogen, which stimulates proliferation of the endometrium. When estrogen reaches a sufficient level and positive feedback mechanisms mature, luteinizing hormone surges and ovulation occurs. After ovulation, the corpus luteum produces progesterone, which transforms the endometrium into a secretory state. If pregnancy does not occur, progesterone and estrogen levels decline, causing shedding of the endometrium and menstrual bleeding.

In adolescent girls, this mature cyclic pattern develops gradually. During the first year after menarche, many cycles are anovulatory because the positive feedback response to estrogen and the luteinizing hormone surge are not yet fully established. Endotext notes that menstrual cycles are usually irregular and anovulatory during the first postmenarchal year, and that maturation of the hypothalamic, pituitary, and ovarian components occurs progressively over several years. By approximately three years after menarche, most cycles become 21–35 days in length.



Normal adolescent menstruation has several characteristic features. The median age of menarche is around 12.4 years. A normal adolescent menstrual cycle usually ranges from 21 to 45 days, menstrual bleeding typically lasts 7 days or less, and average menstrual product use is often around three to six pads or tampons per day. These ranges are broader than adult menstrual norms because adolescent reproductive endocrine regulation is still stabilizing.

Hormonal changes during puberty also influence body composition, skin, mood, and metabolic function. Estrogen promotes breast development, maturation of the uterus and vagina, widening of the pelvis, increased subcutaneous fat deposition in the hips and thighs, and growth of the endometrium. Progesterone becomes more prominent after ovulatory cycles begin and is essential for secretory transformation of the endometrium. Luteinizing hormone and follicle-stimulating hormone regulate ovarian steroidogenesis and follicular maturation. Adrenal androgens contribute to pubic hair, axillary hair, sebaceous gland activity, and sometimes acne. Growth hormone and insulin-like growth factor 1 contribute to the pubertal growth spurt.

The maturation of the menstrual cycle is therefore not only a gynecological process but also an endocrine, metabolic, and neurophysiological process. It reflects the integrated activity of the brain, pituitary gland, ovaries, uterus, adrenal glands, thyroid gland, nutritional status, and general health. Because of this, menstrual irregularity can sometimes be a sign of wider systemic imbalance.

Discussion

The formation of the menstrual cycle in adolescent girls should be understood as a gradual developmental process rather than an immediate transition to adult reproductive function. In clinical practice, one of the most common mistakes is to interpret all irregular cycles after menarche as disease. In reality, mild irregularity during the first one to two years after menarche is often physiological. The immaturity of the hypothalamic–pituitary–ovarian axis leads to inconsistent ovulation, variable follicular phases, and insufficient luteal function. This explains why cycles may be longer, shorter, or unpredictable in early adolescence.

However, physiological irregularity has limits. Menstrual patterns that are extremely abnormal require medical evaluation. Warning signs include absence of menarche by 15 years of age, no menstruation within three years after thelarche, cycles more frequent than every 21 days or less frequent than every 45 days after the early postmenarchal period, cycles longer than 90 days even once, bleeding lasting more than 7 days, very heavy bleeding, symptoms of anemia, severe pelvic pain, signs of androgen excess, sudden weight loss, excessive exercise, galactorrhea, or suspected pregnancy. The American College of Obstetricians and Gynecologists emphasizes that menstruation in girls and adolescents can be used as a “vital sign” because abnormal patterns may reveal important health problems.

Hormonal changes of puberty are closely connected with nutritional and psychosocial factors. Adequate body fat and energy availability are important for normal reproductive axis activation. Undernutrition, eating disorders, chronic illness, psychological stress, and excessive physical activity can suppress gonadotropin-releasing hormone pulsatility and delay or disrupt menstruation. Conversely, obesity and insulin resistance may be associated with earlier puberty, hyperandrogenism, and menstrual irregularity. Genetic background, family history, environmental exposures, sleep patterns, and endocrine-disrupting chemicals may also influence pubertal timing and menstrual maturation.

Another important issue is the relationship between adolescent anovulation and polycystic ovary syndrome. Because irregular cycles are common in early adolescence, polycystic ovary syndrome should not be diagnosed too quickly. Persistent menstrual irregularity beyond the expected



maturation period, especially when accompanied by clinical or biochemical hyperandrogenism such as hirsutism, severe acne, or elevated androgen levels, requires further evaluation. Careful follow-up is important because early identification of endocrine disorders can reduce long-term risks such as infertility, metabolic syndrome, type 2 diabetes, and cardiovascular disease.

Education is a central component of adolescent reproductive health. Many girls experience menarche without adequate information, which may lead to fear, shame, or misunderstanding. Menstrual education should include the meaning of menarche, expected cycle variability, hygiene, pain management, nutrition, warning signs, and when to seek medical care. Parents, teachers, nurses, pediatricians, gynecologists, and family physicians all play an important role in supporting adolescent girls during this transition.

From a public health perspective, menstrual health is also linked to school attendance, psychological well-being, dignity, and access to hygiene products. In some communities, cultural stigma around menstruation can limit girls' participation in education and social life. Therefore, menstrual health should not be considered only a biological issue; it is also a social, educational, and public health priority.

Conclusion

The formation of the menstrual cycle in adolescent girls is a complex and gradual process that reflects the maturation of the hypothalamic–pituitary–gonadal axis and the coordinated function of ovarian, uterine, adrenal, metabolic, and neuroendocrine systems. Menarche is an important milestone of puberty, but regular ovulatory cycles usually develop over several years. Irregular cycles during the first postmenarchal years are often physiological because ovulation and hormonal feedback mechanisms are still maturing.

At the same time, menstruation is an important clinical indicator of adolescent health. Abnormal bleeding patterns, delayed menarche, very heavy menstruation, prolonged amenorrhea, severe pain, or signs of endocrine dysfunction should not be ignored. Proper menstrual education, early recognition of warning signs, healthy nutrition, psychological support, and access to adolescent-friendly healthcare services are essential for protecting reproductive health.

Overall, the study of menstrual cycle formation and pubertal hormonal changes is highly relevant for pediatrics, gynecology, endocrinology, family medicine, and public health. A correct understanding of this process allows healthcare professionals to distinguish normal development from pathology and to support adolescent girls during one of the most important stages of biological and psychosocial maturation.

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