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Stress and the Tick of the Puberty Clock: Effects of Early Life Stress on Timing of Menarche in Females

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ABSTRACT

This review highlights how stress, in any form, impacts the onset of menstruation, where the consequence often includes a lower age at first menstruation. The paper examines 15 significant research studies and how neuro-endocrine pathways, environmental influences, and psychosocial stress interact to contribute to menstrual distress. Although medical practice suggests menarche occurs normally between ages 12 to 14, evidence is accumulating that links stress being a trigger to onset for even as young as 9 years. Findings suggest allostatic load, including increase HPA axis activity and several epigenetic modifications work in concert to cause this. There are also implications for teen health and the need for interventions for the public health sector as it emerges that stress needs to be lowered for kids at risk so that the physical and mental health consequences of early onset menarche are avoided in the future.

Keywords: Stress, Puberty clock, Early life stress, Menstruation, Environmental influence

INTRODUCTION

Menarche, the onset of first menstruation or the first period, is a crucial event for female adolescents and young adults that typically falls between the ages of 12 and 14 years. But there is now a trend where girls younger than age 12 have menarche and this has been associated with increased levels of stress. Stress originating from parents' quarrels, educational pursuit or from financial constraints. The hypothalamic-pituitary-ovary axis is immature in girls in the first two years after menarche begins. Numerous studies describe how lifestyle choices, such as nutrition, exercise, behavior, and menstrual hygiene, can either directly or indirectly affect menstruation and can be changed.

The majority of the study discovered a direct correlation between menstrual irregularities and food, exercise, and menstrual hygiene. Researchers have compiled a list of potential preventative actions that can improve the menstrual health and quality of life of adolescent girls in order to prevent additional complications and diseases related to the menstrual cycle and reproductive organs in young females.

Researchers found that there was a dearth of research on lifestyle change as a means of preventing irregular menstruation. But early etiology sorting and identification are related Adolescent girls with irregular periods were consistently overlooked by medical professionals. Thus, the researcher intends to assess how lifestyle changes affect teenage girls' menstrual illnesses.

Hormonal imbalances brought on by stress have a significant impact on the neuroendocrine system and can hasten puberty. Cortisol levels rise when the hypothalamic-pituitary-adrenal (HPA) axis is chronically activated by stress, interfering with the hypothalamic-pituitary-gonadal (HPG) axis's regular operation. This disturbance speeds up the secretion of gonadotropin-releasing hormone (GnRH), which causes menarche and

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puberty to begin earlier than expected. These neuroendocrine disruptions draw attention to the molecular processes via which stress modifies developmental schedules. This review highlights both biological and psychosocial aspects while synthesizing the body of research on the connection between stress and pubertal timing. Hormonal imbalance is made worse by psychosocial stressors such unstable families, school demands, financial difficulties, and exposure to unfavorable surroundings. In reaction to perceived environmental adversity, these stressors advise the body to mature quickly. Early puberty has important effects on psychological and social development in addition to physical health. Increased risks of mental health issues, obesity, cardiovascular diseases, and reproductive health issues have been associated with early menarche. Early-maturing teenagers also frequently experience emotional difficulties and social pressures, which might impede their general development. It will take a multidisciplinary approach to address these problems. Reducing stress, educating people about menstruation, and creating supportive surroundings are all essential interventions for reducing the long-term health hazards of early puberty.

Literature Review:

Biological Mechanisms:

HPA Axis Dysregulation and Cortisol:

Stress triggers the HPA axis, elevating cortisol levels and disrupting the control of reproductive hormones. Elevated levels of cortisol interfere with the hypothalamic secretion of GnRH, which leads to early release of LH and FSH. Ellis and Essex (2007) indicated that this hormonal disruption leads to acceleration of pubertal changes. Belsky *et al.* (2007) further noted that cortisol directly influences neuroendocrine systems, leading to the earlier activation of the hypothalamic-pituitary-gonadal axis, thus leading to early menarche.

Neuroendocrine Pathways:

HPA activation due to stress causes cascading effects on the neuroendocrine system. The studies by Graber *et al.* (1995) show that chronic stress enhances GnRH secretion, thus increasing LH and FSH levels. This leads to an acceleration of ovarian activity, causing early menarche. Such findings bring into focus the physiological pathways underlying the relationship between stress and reproductive health.

Psychosocial Stressors:

Family Instability:

Family conflict, including parental conflict or absence, is a strong predictor of early menarche. Mendle *et al.* (2012) established that chronic stress from family dysfunction increases cortisol, disrupting the HPA axis and speeding up pubertal timing. Ellis *et al.* (2003) also established father absence and high family stress as key factors increasing the risk of early menarche.

Academic and Peer-Related Stress:

Academic pressure and social comparison are school-related stressors that also precipitate early puberty. Ge *et al.* (2001) found that girls with high levels of academic stress had increased cortisol levels, which accelerated the onset of menarche. Peer relationships and bullying further exacerbate stress and underscore the importance of the social environment in reproductive health.

Economic Difficulty:

Low SES increases the vulnerability of stress and its biological manifestations. According to Deardorff *et al.* (2011), the lack of stability financially would increase cortisol, interfere with hormonal balance, and trigger early menarche. This relationship thus reveals why structural inequalities have to be addressed in interventions designed towards health.

Environmental and Epigenetic Factors:

Epigenetic Mechanisms:

Emerging research has brought out stress-induced epigenetic changes as a mechanism influencing pubertal timing. Tung *et al.* (2017) demonstrated that chronic stress alters gene expression in the HPA and HPG axes, accelerating puberty. Such findings indicate that stress affects not only immediate hormonal regulation but also long-term genetic pathways.

Neighborhood Stressors:

Neighborhood environments that are highly crime-ridden or otherwise unstable increase the stress of girls and its physiological impacts. Lawson *et al.* (2013) noted that girls in high-stress neighborhoods had higher cortisol levels and reached menarche at earlier ages. These findings speak to the intersection of environmental stressors and biological outcomes.

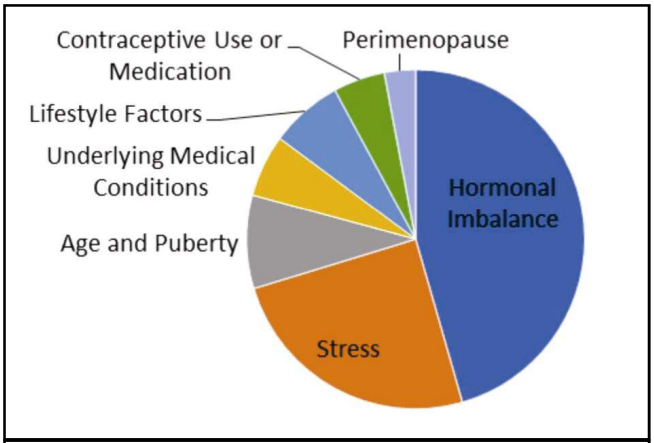

Fig. 1 : Reasons for early menstrual cycles

Hormonal imbalance:

One of the main reasons why menstrual cycles are irregular is hormonal imbalance. Follicle-stimulating hormone (FSH), luteinizing hormone (LH), progesterone, and estrogen are important hormones that control the menstrual cycle. A number of anomalies in their menstruation can result from disturbances in their equilibrium.

Ten per cent or so of women of reproductive age suffer with PCOS, a prevalent endocrine condition. Period irregularities or absence are frequently caused by PCOS, which is characterized by ovarian cysts, insulin resistance, and high androgen levels. Ovulation can be disturbed by hormonal imbalances in PCOS, leading to irregular cycles.

Menstrual patterns can be affected by thyroid disorders, including hyperthyroidism (an overactive thyroid) and hypothyroidism (an underactive thyroid). The thyroid gland affects hormones involved in reproduction and controls metabolism. While hypothyroidism might lead to heavy or protracted periods, hyperthyroidism frequently produces lighter, less.

Hormonal Changes:

Adolescence and the perimenopause are times of major hormonal shifts. Uneven menstrual cycles may result from changing hormone levels during various stages; these cycles may eventually return to normal once hormonal stability is attained

Stress:

Stress has a significant impact on hormone balance, whether it be physical or emotional. Menstrual cycle regulation is regulated by the hypothalamic-pituitary-ovarian (HPO) axis, which can be interfered with by the hypothalamic-pituitary-adrenal (HPA) axis, which controls the body's stress response.

Emotional Stress:

Acute or chronic emotional distress can prevent gonadotropin-releasing hormone (GnRH) from being released, which can cause delayed ovulation or anovulation. Period irregularities, missing periods, or particularly heavy periods may result from this.

Menstrual cycles may be momentarily disrupted by physical stressors such as surgery, illness, or injury. The body may preserve energy in response to severe physical stress, which could impact reproductive processes and change menstrual cycles.

Diet and nutrition :

The health of menstruation is greatly influenced by diet and nutritional state. Abrupt weight swings, severe dieting, or nutritional deficits might throw off menstruation regularity and hormonal balance.

Deficiencies in nutrition:

Hormonal function can be affected by inadequate consumption of vital nutrients, including iron, zinc, vitamin D, and B vitamins. For instance, irregular cycles can be sustained by low iron levels, which are frequently brought on by excessive menstrual bleeding.

Unexpected Weight Changes:

Quick weight reduction or gain affects leptin synthesis, which controls reproductive hormones. Hyperandrogenism and insulin resistance, which are symptoms of PCOS, can result from excessive weight gain. Amenorrhea, on the other hand, might result from ovulation suppression caused by underweight or eating disorders.

Disordered Eating:

Disorders such as bulimia and anorexia nervosa can lead to irregular or nonexistent periods by suppressing reproductive hormone levels. To restore hormonal balance, a balanced diet must be resumed.

Age and puberty:

Age has a significant impact on menstrual regularity. Adolescence and the years preceding menopause are

characterized by irregular cycles.

The body develops a regular ovulation pattern as the reproductive system matures during puberty and adolescence. During the course of this procedure, which might take years, irregular periods are common. Hormonal rhythms eventually become regular, and cycles usually settle.

Perimenopause:

Usually beginning in the late 40s or early 50s, the years preceding menopause are characterized by varying levels of progesterone and estrogen. Frequently, these hormonal changes result in severe bleeding, irregular cycles, or missed periods. Keeping track of symptoms and consulting a doctor might help you properly manage these changes.

Underlying medical condition:

Menstrual abnormalities can result from a variety of medical problems that affect menstrual health.

Uterine fibroids:

Prolonged, heavy, or irregular bleeding may be caused by noncancerous growths in the uterus. If fibroids are not treated, they can lead to discomfort, anemia, and other problems.

Endometriosis:

This disorder develops when uterine lining-like tissue proliferates outside the uterus. It frequently results in irregular cycles, spotting in between periods, and uncomfortable periods.

Chronic Illnesses:

Diabetes, celiac disease, and autoimmune illnesses are among the conditions that might affect menstruation health. Diabetes that is not properly controlled, for instance, might alter hormone levels and cause irregular periods.

Pituitary Disorders:

FSH and LH, two important hormones in the control of menstruation, can be produced in response to tumors or deficiencies in the pituitary gland.

Life style factor:

Menstrual abnormalities are frequently caused by modern lifestyle choices, such as excessive activity, poor sleep, and harmful habits.

Excessive Exercise:

Amenorrhea can result from suppressing the synthesis of reproductive hormones, especially in athletes. Excessive training might cause energy imbalances that interfere with ovulation.

Lack of sleep has an impact on the circadian rhythm, which is directly related to hormone synthesis. Long-term sleep deprivation can cause irregular cycles.

Substance Abuse:

Misuse of recreational drugs, excessive drinking, and smoking can disrupt menstruation health and hormonal balance.

Contraceptive use of medications:

Some drugs might affect menstrual cycles, especially hormonal contraceptives.

Hormonal contraceptives:

To control cycles, birth control pills, patches, or intrauterine devices (IUDs) adjust hormone levels. However, they may result in irregular bleeding, especially after stopping the medication or during the first few months of treatment.

Emergency Contraception:

When taken as emergency contraception, high-dose hormone pills may cause temporary disruptions to the menstrual cycle, including as delays or variations in flow.

Drugs that disrupt hormonal or systemic processes, such as anticoagulants, antipsychotics, and chemotherapeutic drugs, can have an impact on menstrual periods

Perimenopause:

Significant hormonal changes occur during the perimenopause, the period of transition before menopause. Frequently, these variations lead to irregular menstrual cycles.

Hormonal Changes:

Unpredictable levels of progesterone and estrogen are caused by declining ovarian function, which results in irregular periods. Mood swings, nocturnal sweats, and hot flashes are among symptoms that may be present during this time.

Symptom Management:

Hormone replacement treatment (HRT), lifestyle changes, and routine checkups with a doctor can all help people get through perimenopause successfully.

Between 2013 and 2022, the percentage of women reporting early periods consistently rose, reflecting the growing impact of various lifestyle, medical, and environmental factors. In 2013, about 21% of women reported experiencing early menstrual cycles, primarily influenced by hormonal imbalances, stress, and related factors. By 2014, the percentage rose slightly to 22%, as increasing awareness of menstrual irregularities brought more cases to light. In 2015, this pattern continued, with 25% of women citing problems with stress, dietary adjustments, and other interruptions in their lifestyle. Since more women were able to identify alterations in their menstrual cycles thanks to the widespread use of health tracking apps and medical education, the percentage rose to 28% in 2016. Urbanization, work-related stress, and other pressures of contemporary life were major causes of the percentage's rise to 29% in 2017. The rising use of hormonal contraceptives and changes in fitness and nutrition habits contributed to 30% of women reporting early periods in 2018. As women's health issues gained more attention and reporting systems improved, the percentage increased to 33% by 2019. A record-breaking increase was brought on by the COVID-19 pandemic in 2020, when 36% of women reported having their periods early because of increased stress, disturbed routines, and limited access to medical treatment. In 2021, the percentage of people recovering from the pandemic stabilized slightly, falling to 33% as people adjusted to the "new normal". But in 2022, the percentage increased once more to 35% due to ongoing lifestyle pressures,

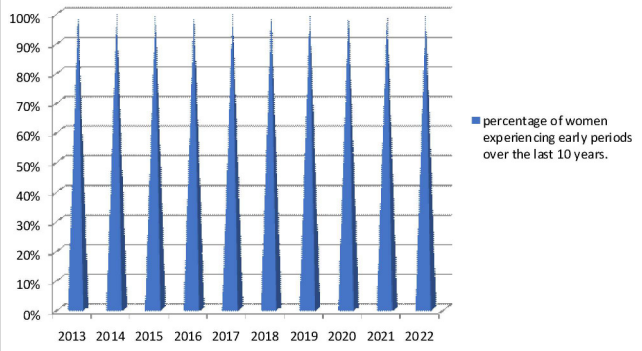

Fig. 2 : Trend of Early Onset of Mensturation in Women (Last 10 years)

illnesses, and a sustained emphasis on menstrual health awareness. Over the course of the decade, these patterns highlight the intricate interactions between societal, emotional, and physical factors that affect women's reproductive health (Fig. 2)

A delicate balance between biological, psychological, and environmental factors is reflected in the complex association between stress and early menarche. Prolonged stress causes the hypothalamic-pituitary-adrenal (HPA) axis to become active, which raises cortisol levels. Long-term dysregulation of cortisol disrupts the hypothalamic-pituitary-gonadal (HPG) axis, which controls the production of reproductive hormones. This disturbance can cause early menarche by prematurely initiating the release of gonadotropin-releasing hormone (GnRH), which can hasten the onset of puberty. Psychosocial factors that exacerbate this biochemical process include parental conflict, family instability, and the lack of a caregiver. Elevated stress hormones in children from difficult family circumstances might cause the body to mature prematurely in response to perceived adversity. The likelihood of early menarche is increased by the extra stressors of academic pressures and socioeconomic difficulties. The stress load is further raised by living in an urban environment, which has more pollution exposure, a dense population, and fast-paced lifestyles. Stress during crucial embryonic stages can result in permanent genetic changes, according to new epigenetic studies. Puberty may be accelerated by these alterations, which may involve the methylation of genes linked to hormone regulation. The consequences of chronic stress are further exacerbated by environmental stressors, including as exposure to endocrine-disrupting chemicals in food, water, and personal care products, highlighting the intricate interaction between internal and external variables that shapes reproductive development.

Addressing these findings through public health initiatives is a priority. Interventions aimed at reducing stress in at-risk populations, such as resilience training, mental health support, and socioeconomic assistance, may minimize the negative impacts of early menarche on long-term health outcomes.

Conclusion:

Early menarche is significantly impacted by stress through complex biological and psychological processes. The hypothalamic-pituitary-adrenal (HPA) axis is activated by chronic stress, which is frequently brought

on by difficult family situations, academic demands, and financial difficulties. This causes the hypothalamic-pituitary-gonadal (HPG) axis to be upset, resulting in increased cortisol levels and hormonal abnormalities that hasten puberty. Psychosocial stressors can also exacerbate these effects by causing the body to adjust by increasing reproductive maturity in response to unfavorable circumstances. Wide-ranging effects of early menarche include heightened vulnerability to mental health issues, obesity, cardiovascular disease, and difficulties with reproduction in later life. This emphasizes how crucial focused interventions are in addressing the pressures that young women face. One of the most important ways to lessen the negative consequences of long-term stress is to create supportive circumstances, such as stable family dynamics, less academic pressure, and easy access to mental health resources.Policy-level and community-level activities are also crucial. These include encouraging school-based stress management initiatives, guaranteeing fair access to medical care, and tackling socioeconomic inequalities. Adolescents who receive early instruction on stress management techniques and menstrual health awareness can be better equipped to handle obstacles. We can promote healthy transitions into adulthood, lower health risks, and improve teenage well-being by proactively addressing these stressors.

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