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SLEEP LOSS, EVENING LIGHT EXPOSURE, STRESS PHYSIOLOGY, AND INSULIN SIGNALING AS INTERACTING DRIVERS OF MENSTRUAL IRREGULARITY IN ADOLESCENT GIRLS

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Abstract. Menstrual cycle irregularity and cyclic symptom burden are common during adolescence and may reflect dysregulation across neuroendocrine, metabolic, and stress-response systems. Modern adolescent lifestyles combine several exposures that can destabilize menstrual regularity, including short sleep duration, evening light and screen exposure, psychosocial stress, irregular meal timing, and low physical activity. Population studies show that shorter sleep duration and poor sleep quality are associated with increased menstrual irregularity and more severe dysmenorrhea and premenstrual symptoms. Experimental evidence demonstrates that sleep deprivation rapidly induces insulin resistance and alters cortisol rhythms. Evening light exposure suppresses melatonin secretion, delaying sleep onset and weakening the biological night signal. These endocrine and metabolic changes may influence hypothalamic–pituitary–ovarian axis regulation and ovarian steroidogenesis. A mechanistic framework integrating melatonin suppression, HPA-axis activation, and reduced insulin sensitivity explains how adolescent lifestyle patterns can increase menstrual variability and symptom severity. Preventive strategies should therefore focus on improving sleep regularity, reducing evening light exposure, managing stress, and stabilizing metabolic routines.

Keywords: adolescence, menstrual irregularity, sleep disturbance, melatonin, cortisol, insulin resistance, dysmenorrhea, circadian disruption

Annotatsiya. O‘smir qizlarda menstrual siklning buzilishi keng tarqalgan bo‘lib, u neyroendokrin, metabolik va stress tizimlaridagi o‘zgarishlar bilan bog‘liq bo‘lishi mumkin. Zamonaviy turmush tarzi omillari, jumladan uyqu yetishmasligi, kechki sun’iy yorug‘lik va ekranlardan foydalanish, psixologik stress, noto‘g‘ri ovqatlanish va past jismoniy faollik menstrual sikl barqarorligiga salbiy ta’sir ko‘rsatadi. Tadqiqotlar shuni ko‘rsatadiki, qisqa uyqu davomiyligi va uyqu sifati yomonligi menstrual siklning buzilishi hamda dismenoreya va premenstrual simptomlarning kuchayishi bilan bog‘liq. Uyqu yetishmovchiligi insulin rezistentligi va kortizol ritmlarining o‘zgarishiga olib kelishi mumkin, kechki yorug‘lik esa melatonin sekretsiyasini bostirib, biologik ritmlarni buzadi. Ushbu endokrin va metabolik o‘zgarishlar gipotalamus–gipofiz–tuxumdon tizimi faoliyatiga ta’sir qilib, menstrual siklning beqarorlashuviga sabab bo‘lishi mumkin. Shu sababli o‘smir qizlarda reproduktiv salomatlikni saqlash uchun uyqu gigiyenasini yaxshilash, kechki yorug‘lik ta’sirini kamaytirish, stressni boshqarish va metabolik tartibni barqarorlashtirish muhim ahamiyatga ega.

Kalit so‘zlar: o‘smirlik davri, menstrual sikl buzilishi, uyqu buzilishi, melatonin, kortizol, insulin rezistentligi, dismenoreya, biologik ritm buzilishi

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Аннотация. Нарушения менструального цикла у подростков встречаются достаточно часто и могут отражать дисрегуляцию нейроэндокринных, метаболических и стресс-ответных систем организма. Современный образ жизни подростков включает ряд факторов, способных нарушать регулярность менструального цикла: недостаточную продолжительность сна, воздействие вечернего искусственного света и экранов, психоэмоциональный стресс, нерегулярное питание и низкую физическую активность. Эпидемиологические исследования показывают, что короткая продолжительность сна и плохое качество сна связаны с более высокой частотой нарушений менструального цикла, дисменореи и предменструальных симптомов. Экспериментальные данные свидетельствуют, что депривация сна может вызывать инсулинорезистентность и изменять ритмы секреции кортизола, тогда как вечернее освещение подавляет секрецию мелатонина и нарушает циркадные ритмы. Эти эндокринные и метаболические изменения могут влиять на регуляцию гипоталамо-гипофизарно-яичниковой системы и способствовать возникновению менструальных нарушений. Профилактические меры должны быть направлены на улучшение гигиены сна, снижение воздействия вечернего света, управление стрессом и стабилизацию метаболических процессов.

Ключевые слова: подростковый возраст, нарушение менструального цикла, нарушения сна, мелатонин, кортизол, инсулинорезистентность, дисменорея, циркадные ритмы

Introduction

The menstrual cycle is increasingly recognized as an important indicator of adolescent health. Persistent irregular cycles, excessive bleeding, or severe menstrual symptoms may reflect endocrine or metabolic dysregulation rather than normal developmental variation. Clinical guidelines therefore recommend using menstrual patterns as a “vital sign” for assessing adolescent health (1).Adolescence is characterized by biological shifts in circadian rhythms that delay sleep timing. When combined with early school schedules, evening screen exposure, and psychosocial stress, these changes often lead to chronic sleep restriction. Sleep disturbances influence several endocrine systems, including melatonin secretion, cortisol rhythms, and insulin sensitivity. These systems interact closely with reproductive physiology and can influence hypothalamic–pituitary–ovarian (HPO) axis regulation (2–4).

Literature Review and Methodology

This study is based on a narrative review of scientific literature examining the relationship between sleep patterns, circadian disruption, metabolic regulation, and menstrual health in adolescents. Relevant publications were identified through academic databases including PubMed, ScienceDirect, and Google Scholar. Keywords used in the search included *adolescent sleep*, *menstrual irregularity*, *circadian rhythm*, *melatonin*, *cortisol*, and *insulin resistance*.

Several epidemiological studies have investigated the relationship between sleep patterns and menstrual health in adolescents. Population-based research in Korean adolescent girls demonstrated that short sleep duration is associated with increased risk of menstrual cycle irregularity (2). Additional cohort studies have reported that sleep disturbance and delayed sleep timing are associated with menstrual pain, functional impairment, and premenstrual symptoms (3,4).

Experimental studies provide mechanistic explanations for these associations. Sleep restriction has been shown to alter cortisol dynamics and impair glucose metabolism, increasing insulin resistance (8–10). Insulin resistance can influence ovarian steroidogenesis and modify the bioavailability of reproductive hormones through changes in sex hormone binding globulin.

Furthermore, evening light exposure suppresses melatonin secretion, which delays sleep onset and disrupts circadian regulation. Because melatonin also plays roles in ovarian physiology and follicular protection, chronic melatonin suppression may indirectly influence reproductive health (6,7).

Results

The reviewed evidence demonstrates consistent associations between poor sleep patterns and menstrual disturbances in adolescents. Short sleep duration and irregular sleep timing are linked with higher prevalence of menstrual irregularity, dysmenorrhea, and premenstrual symptoms (2–5).

Physiological studies show that sleep restriction can rapidly reduce insulin sensitivity and alter cortisol secretion patterns (8–10). These endocrine changes may interfere with hypothalamic signaling and ovarian hormone production, contributing to irregular ovulation and hormonal imbalance.

Evening exposure to artificial light further contributes to these effects by suppressing melatonin production and delaying circadian rhythms (6,7). This combination of circadian disruption, metabolic stress, and endocrine changes forms a biologically plausible pathway linking modern lifestyle patterns to menstrual disturbances in adolescents.

Discussion

The findings suggest that menstrual irregularity in adolescents may result from interactions between developmental hormonal changes and environmental exposures. Sleep loss, circadian disruption, psychosocial stress, and metabolic imbalance appear to form a reinforcing cycle.

Insulin resistance is a particularly important factor because it directly affects ovarian steroidogenesis and is a key feature of conditions such as polycystic ovary syndrome (11). Although not all adolescents with irregular cycles develop PCOS, early metabolic disturbances may increase vulnerability to reproductive disorders later in life.

Melatonin also plays protective roles in ovarian physiology and follicular development. Disruption of melatonin secretion due to nighttime light exposure may therefore influence reproductive health through multiple endocrine pathways (12).

These observations highlight the importance of preventive strategies targeting modifiable lifestyle factors. Improving sleep hygiene, reducing evening light exposure, managing stress, and maintaining regular meal timing may help stabilize endocrine and metabolic regulation.

Conclusion

Adolescent menstrual health is influenced by complex interactions between circadian biology, metabolic regulation, and reproductive endocrine function. Short sleep duration, evening light exposure, psychosocial stress, and metabolic disruption can collectively destabilize menstrual cycle regulation through mechanisms involving melatonin suppression, HPA-axis activation, and reduced insulin sensitivity. Evidence from epidemiological and experimental studies supports the role of sleep and circadian health as important determinants of menstrual function in adolescents. Interventions aimed at improving sleep patterns, minimizing evening light exposure, and stabilizing daily routines represent promising strategies for supporting adolescent reproductive health.

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