JoFA

ORIGINAL RESEARCH ARTICLE

Hormonal disorders and acne severity in women aged 18–50: the role of PCOS and insulin resistance

Dominika Bednarska[1, a], Iwona Pordąb[2, b]*

[1] –
[2] Department and Division of Practical Cosmetology and Prevention of Skin Diseases, Faculty of Pharmacy, Poznan University of Medical Sciences, Poland

[a] https://orcid.org/0009-0008-1582-0390 [b] https://orcid.org/0000-0002-8947-9999

DOI: https://doi.org/10.20883/jofa.131

*** Corresponding author:**
pordab@ump.edu.pl

ABSTRACT

Background. Acne in young and adult women is a chronic hormonal-metabolic dermatosis that significantly impairs self-esteem and quality of life, owing to its predominantly facial distribution.
Aim. To assess the relationship between selected endocrine disorders – polycystic ovary syndrome (PCOS), insulin resistance, hyperandrogenism, and thyroid disease – and acne severity in women aged 18–50, and to evaluate patients' subjective skin assessments and the outcomes of hormonal treatment.
Material and methods. One hundred women aged 18–50 with self-reported skin problems completed an original online questionnaire covering sociodemographic data, diagnosed endocrine disorders, acne characteristics, skin hydration and sebum secretion, and the perceived effect of hormonal treatment. Statistical analysis was performed using the chi-square test ($p < 0.05$).
Results. Hormonal disorders were identified in 63% of participants, most commonly PCOS and insulin resistance (21% each). Acne was reported by 79% of women; moderate-to-severe disease predominated in those with hyperandrogenism (91.7%), PCOS (78.3%), and insulin resistance (72%; $\chi^2 = 133.84$; $p = 0.0019$). No significant association was found between hormonal disorders and skin hydration or sebum secretion. Women receiving hormonal treatment more frequently reported skin improvement than untreated women (50% vs. 27.4%; $\chi^2 = 14.64$; $p = 0.0055$).
Conclusions. Acne in adult women is strongly linked to endocrine disturbances – particularly PCOS and insulin resistance – underscoring the need for hormonal-metabolic work-up in patients with moderate-to-severe disease and for a holistic therapeutic approach that addresses both systemic causes and psychosocial burden.

Keywords: acne, adult women, hormonal disorders, insulin resistance, polycystic ovary syndrome.

Introduction

Acne in young and adult women is a chronic inflammatory disease of the pilosebaceous unit that may persist from adolescence or present de novo as early-onset adult or post-adolescent acne [1,2]. Lesions are predominantly facial, with a predilection for the lower face – the jawline, chin, and neck (the so-called U-zone) – so that even moderate severity substantially impairs self-esteem, quality of life, and social functioning [1,3]. Because acne frequently coexists with hormonal and metabolic disorders, it should be regarded not only as a cosmetic concern but also as a potential marker of underlying systemic abnormalities [4,5].

Chronic acne is associated with reduced self-esteem, shame, social withdrawal, and an elevated risk of anxiety and depressive symptoms; its psychosocial burden is comparable to that of other chronic somatic diseases, as confirmed by dermatology-specific quality-of--life instruments such as the DLQI [6,7]. A prospective Polish study further demonstrated that women with acne – despite milder clinical disease – report significantly worse quality of life, higher levels of stigmatisation, and greater anxiety than their male counterparts, highlighting the psychosocial vulnerability of this patient group [8]. In the context of hormonal disorders such as PCOS and insulin resistance, the presence of moderate-to-severe acne further aggravates body-image disturbance and the sense of chronic illness, reinforcing the need for a holistic, psychologically informed therapeutic approach. Understanding the pathomechanism of these changes requires an analysis of systemic factors, among which hormonal regulation plays a central role [9].

Steroid hormones – including androgens, oestrogens, and progesterone – regulate facial skin homeostasis through interactions with nuclear receptors: androgen receptors (AR), oestrogen receptors alpha and beta (ERα, ERβ), and progesterone receptors (PR), all of which are expressed in keratinocytes, fibroblasts, sebocytes, and hair-follicle cells. This hormonal balance is essential for maintaining the epidermal barrier; its dysregulation underlies a broad spectrum of dermatoses, ranging from acne to accelerated skin ageing [4,10].

Androgens – particularly dihydrotestosterone (DHT), converted from testosterone by 5α-reductase – potently stimulate sebogenesis, resulting in seborrhoea and impaired barrier function [11,12]. Excess androgen activity also promotes microbiome dysbiosis by creating a lipid-rich environment. Critically, current evidence revises the simple model of bacterial overgrowth in favour of a dysbiosis framework: the lipid-enriched milieu selectively promotes the pro-inflammatory phylotype IA1 of *Cutibacterium acnes* at the expense of commensal *Staphylococcus epidermidis*, triggering innate immune activation and biofilm formation that together underpin the pathomechanism of inflammatory lesions [13–15].

Oestrogens, acting through both genomic and non-genomic pathways, promote keratinocyte proliferation, collagen and hyaluronic acid synthesis, and lipid barrier reinforcement via ceramide production – a mechanism central to delaying skin ageing and preventing excessive dryness [16,17]. Progesterone, via the progesterone receptor, exerts anti-inflammatory effects and inhibits 5α-reductase activity, thereby attenuating DHT-mediated stimulation of sebaceous glands – a mechanism of particular relevance in states of androgen excess [10]. Stress hormones, including cortisol and corticotropin-releasing hormone (CRH), also modulate sebaceous gland function and inflammatory tone, although the direct impact of psychological stress on sebum production varies according to individual predisposition [18,19].

These hormonal interactions acquire particular clinical relevance in adult women, where chronic inflammatory dermatoses such as acne frequently co-occur with systemic endocrine disorders including PCOS and insulin resistance, creating a self-perpetuating cycle of inflammatory mechanisms [20,21].

Aim

The aim of this study was to assess the influence of hormonal disorders – particularly PCOS, insulin resistance, and hyperandrogenism – on the prevalence and severity of acne in adult women, and to analyse patients' subjective skin assessments and the perceived effects of hormonal treatment.

Material and methods

The study employed a diagnostic survey method among women with self-reported skin problems; participation was voluntary and

anonymous. The research instrument was an original online questionnaire comprising: socio-demographic data (age, BMI); medical history regarding diagnosed endocrine disorders (PCOS, insulin resistance, hyperandrogenism, thyroid disease); characterisation of skin lesions (acne severity, seborrhoea, hair growth abnormalities); and a subjective assessment of skin condition and skincare practices.

One hundred women aged 18–50 were included in the analysis, with a predominance of participants aged 18–25 (78%) and a mean BMI of 20.4 kg/m², within the normal body-weight range. Recruitment was conducted among patients of dermatological and cosmetological practices and among users of online thematic forums dedicated to skin problems.

Since the acne severity question permitted multiple responses, each participant was assigned to a single severity category based on the most severe response selected (severe > moderate > mild > no acne). Perimenstrual acne exacerbation was treated as a separate clinical variable and excluded from the severity classification, ensuring mutually exclusive categories for statistical analysis.

The collected data were analysed using Pearson's chi-square test (χ^2) with a significance level of $p < 0.05$.

Results

Characteristics of the study group

The study included 100 women aged 18–50, of whom 60% were students and 40% were employed. The dominant age group was 18–25 years (78%), while older groups (26–35, 36–45, and 46–50 years) accounted for 10%, 11%, and 1% of participants, respectively. The majority had a normal body weight (mean BMI 20.4 kg/m²), enabling analysis of hormonal influences on skin condition with limited confounding from BMI extremes.

Body weight changes and hormonal medications

More than one-third of participants (39%) reported weight gain over the previous two years, 15% reported weight loss, and 46% reported no significant change. The majority (84%) were not taking any hormonal medications other than contraceptives, while 16% used such preparations (including thyroid medications and metformin).

Diagnosed hormonal disorders and skin changes

Among participants, 37% had no diagnosed hormonal disorder, while a significant proportion had PCOS (21%), insulin resistance (21%), or hypothyroidism (18%). Additionally, 24% of participants were uncertain whether they had a hormonal disorder, suggesting a potentially underdiagnosed subgroup. The most commonly reported skin changes in women with hormonal disorders were: acne exacerbation (36%), changes in hair growth (23%), and excessive sebum secretion (17%) (see **Table 1**).

▼ Table 1. Skin changes in participants with hormonal disorders (multiple-response question)

Skin change	% of respondents*
Acne exacerbation	36.0
Changes in hair growth	23.0
Excessive sebum secretion	17.0
Excessive skin dryness	6.0
Hyperpigmentation	5.0
No changes / not applicable	56.0

* Percentage within the hormonal-disorder group; multiple responses permitted.

Subjective assessment of skin, hydration, and sebum

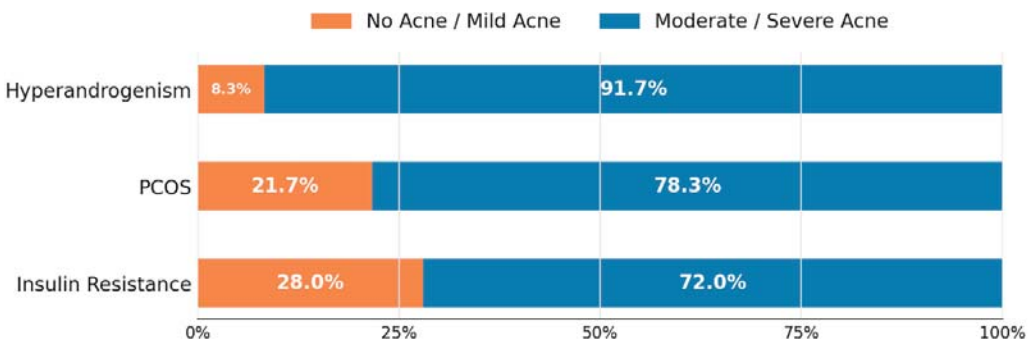
Most women rated their overall skin condition as average or good; fewer than one-fifth gave negative ratings (1–2 on a 1–5 scale). The distribution of responses regarding skin hydration and sebum secretion levels is presented in **Table 2**.

▼ Table 2. Subjective assessment of skin hydration and sebum secretion

Response	Skin hydration n (%)	Sebum secretion n (%)
Very low	5 (5.0)	14 (14.0)
Low	18 (18.0)	17 (17.0)
Average	67 (67.0)	51 (51.0)
High	9 (9.0)	17 (17.0)
Very high	1 (1.0)	1 (1.0)

Acne and its association with hormonal disorders

Acne was reported by 79% of participants; the most common forms were mild (38%) and moderate (30%), while severe acne was declared by 5% of women. Additionally, 26% of respondents observed acne exacerbation around men-



▲ Figure 1. Acne severity distribution across hormonal disorder subgroups.

struation, underscoring the role of hormonal fluctuations. Cross-tabulation analysis showed that moderate-to-severe acne was most prevalent in women with hyperandrogenism (91.7%), PCOS (78.3%), and insulin resistance (72%) (see **Figure 1**). The chi-square test ($\chi^2 = 133.84$; $p = 0.0019$) confirmed a statistically significant association between hormonal disorders and acne severity.

Perimenstrual acne exacerbation was excluded from severity classification. $\chi^2 = 133.84$; $p = 0.0019$.

Sebum, skin hydration, and hormonal disorders

Analysis of the relationship between diagnosed hormonal disorders and sebum secretion revealed no significant differences; average sebum levels predominated across most groups. The chi-square test ($\chi^2 = 70.75$; $p = 0.1614$) did not confirm a significant association between hormonal disorders and seborrhoea. Similarly, average hydration levels prevailed regardless of the type of hormonal disorder, and the chi-square test ($\chi^2 = 53.12$; $p = 0.7232$) did not demonstrate a significant relationship between hormonal disorders and skin hydration.

Hormonal contraception, hormonal treatment, and skin condition

Hormonal contraception was currently used by 40% of participants, 27% had used it in the past, and 33% had never used it. Among women using contraception, slight or marked improvement in skin condition was most frequently reported, although some noted no change and a minority experienced deterioration. Regarding other hormonal medications (not contraceptives), skin improvement (slight or significant) was declared by 50% of women taking such preparations, compared with 27.4% in the untreated group. The chi-square test ($\chi^2 = 14.64$; $p = 0.0055$) confirmed a statistically significant association between hormonal medication use and self-reported skin improvement.

Discussion

Recent literature emphasises that acne in young and adult women extends beyond an aesthetic concern, constituting a substantial burden on mental health, self-esteem, and quality of life [22]. Chronic inflammatory lesions in such a visible area as the face predispose to diminished sense of attractiveness, social isolation, and heightened anxiety and depressive symptoms, as demonstrated in studies using dermatology-specific quality-of-life tools (DLQI, CADI, HADS) [6]. In this context, the primary therapeutic goal extends beyond lesion reduction to minimising the psychosocial impact of the disease – a shift away from purely symptomatic treatment towards identification of its systemic causes [22].

The findings of the present study clearly confirm a close relationship between systemic disorders and skin condition. The highly significant correlation ($p = 0.0019$) between acne severity and insulin resistance (72% of severe cases) and PCOS (78.3%) aligns with the concept of metabolic dermatology and highlights the insulin–IGF-1 axis as a key driver of lipogenesis and hyperkeratinisation in adult acne. These data are consistent with the literature, in which insulin resistance and hyperinsulinaemia are recognised as important pathogenic factors in acne, particularly in women with PCOS [23].

Given the high proportion of participants with insulin resistance, the role of metformin warrants particular attention. Evidence indicates that this drug – at standard doses – not only reduces glycaemia but also lowers ovarian hyperandrogenism by improving tissue insulin

sensitivity, resulting in clinical improvement of acne in women with PCOS and insulin resistance. Its mechanism involves activation of AMPK kinase and secondary inhibition of the mTORC1 pathway, leading to reduced sebum production and attenuation of follicular inflammation [24].

For patients seeking an alternative to synthetic pharmacotherapy, berberine represents a promising option; its metformin-mimetic activity has been confirmed in recent studies. This alkaloid, administered at 3 × 500 mg, activates AMPK, reduces pro-inflammatory cytokines, and improves insulin sensitivity – effects that may translate into reduced inflammatory lesion severity in women with metabolic disorders and adult acne [25].

With respect to hormonal contraception, the present study found approximately 50% skin improvement in women using this form of therapy, consistent with current evidence in which hormonal contraceptives are recognised as a meaningful component of acne management in women. Combined oral contraceptives containing anti-androgenic progestogens – such as drospirenone and dienogest – show particularly favourable profiles; their mechanism involves androgen receptor blockade and inhibition of 5α-reductase activity. These preparations are recommended for acne with a hyperandrogenic aetiology, which also predominated among patients with the most severe disease in the present study [26–28]. Among other anti-androgenic agents, spironolactone has also demonstrated efficacy in adult female acne with a hyperandrogenic background, particularly in patients for whom combined oral contraceptives are contraindicated [26,29].

An intriguing finding was the absence of a statistically significant association between hormonal disorders and either skin hydration or sebum secretion – a result that may seem paradoxical given classical models of acne pathogenesis. This should be interpreted in light of current concepts that emphasise not so much the quantity of sebum as the alteration of its composition (lipid dysbiosis) and disruption of the epidermal barrier, which is frequently a consequence of aggressive skincare routines and inappropriate cosmetic procedures [13,30]. This underscores the need for concurrent skincare aimed at restoring the hydrolipid barrier – particularly in patients with severe acne and impaired quality of life [5].

Emerging evidence also implicates the gut–skin axis in the pathogenesis of hormonal acne in adult women [31]. Dysbiosis of the intestinal microbiome – increasingly documented in women with PCOS [32] – can impair oestrogen metabolism, amplify androgen activity, and sustain low-grade systemic inflammation, thereby promoting acneic lesions independently of cutaneous sebaceous gland activity. A 2025 study identified elevated serum trimethylamine N-oxide (TMAO) levels – a gut-derived metabolite – in acne vulgaris patients, suggesting a mechanistic link between dietary patterns, intestinal dysbiosis, and acne pathogenesis [33]. These findings are further supported by a recent review demonstrating that gut microbiome alterations in PCOS-associated acne reinforce the hyperandrogenism–insulin resistance cycle [34], pointing to probiotic supplementation and low-glycaemic dietary intervention as adjunctive strategies deserving further clinical investigation [32].

Several limitations of the present study should be acknowledged. The cross-sectional, self-reported design precludes causal inference, and acne severity was assessed subjectively rather than by validated clinical tools (e.g., IGA scale). The sample was predominantly young women aged 18–25, limiting generalisability to older adult cohorts. Furthermore, recruitment through online forums may have introduced selection bias towards women with greater health awareness or more severe skin concerns. Future studies employing clinical examination, biochemical hormonal profiling, and validated severity scales in larger, age-stratified samples are warranted to confirm and extend the present findings.

Taken together, the findings indicate that modern management of acne in adult women cannot be limited to topical interventions alone. Optimal care should encompass targeted endocrine and metabolic treatment – addressing PCOS, insulin resistance, and thyroid disorders – complemented by patient education regarding skincare and, where indicated, psychological support, with the long-term aim of mitigating the negative impact of the disease on self-esteem and quality of life.

List of abbreviations:

AMPK	AMP-activated protein kinase
AR	androgen receptor
BMI	body mass index
CADI	Cardiff Acne Disability Index

CRH	corticotropin-releasing hormone
DHT	dihydrotestosterone
DLQI	Dermatology Life Quality Index
ERα	oestrogen receptor alpha
ERβ	oestrogen receptor beta
HADS	Hospital Anxiety and Depression Scale
IGA	Investigator's Global Assessment
IGF-1	insulin-like growth factor 1
mTORC1	mechanistic target of rapamycin complex 1
PCOS	polycystic ovary syndrome
PR	progesterone receptor
TMAO	trimethylamine N-oxide

Declarations

Conflict of interest statement
The authors declares no conflict of interest.

Funding sources
There are no sources of funding to declare.

References

1. Skroza N, Tolino E, Mambrin A, Zuber S, Balduzzi V, Marchesiello A, et al. Adult acne versus adolescent acne: a retrospective study of 1,167 patients. J Clin Aesthet Dermatol. 2018;11(1):21-25. PMID: 29410726; PMCID: PMC5788264.
2. Dréno B, Thiboutot D, Layton AM, Berson D, Perez M, Kang S. Large-scale international study enhances understanding of an emerging acne population: adult females. J Eur Acad Dermatol Venereol. 2015;29(6):1096-1106. doi: 10.1111/jdv.12757.
3. Sharma R, Dogra N, Arora M. Psychosocial impact of acne vulgaris on the quality of life among adolescents versus adults. Clin Med (Lond). 2023;23(Suppl 6):35. doi: 10.7861/clinmed.23-6-s35.
4. Ju Q, Tao T, Hu T, Karadağ AS, Al-Khuzaei S, Chen WC. Sex hormones and acne. Clin Dermatol. 2017;35(2):130-137. doi: 10.1016/j.clindermatol.2016.10.004.
5. Layton AM, Gupta G, Seukeran D, Maruthappu T, Gaillard S, Whitehouse H, et al. What's new after NICE acne guidelines. Dermatol Ther (Heidelb). 2024;14(10):2727-2738. doi: 10.1007/s13555-024-01275-0.
6. Morshed ASM, Noor T, Uddin Ahmed MA, Mili FS, Ikram S, Rahman M, et al. Understanding the impact of acne vulgaris and associated psychological distress on self-esteem and quality of life via regression modeling with CADI, DLQI, and WHOQoL. Sci Rep. 2023;13(1):21084. doi: 10.1038/s41598-023-48182-6.
7. Tan J, Beissert S, Cook-Bolden F, Chavda R, Harper J, Hebert A, et al. Impact of facial and truncal acne on quality of life: a multi-country population-based survey. JAAD Int. 2021;3:102-110. doi: 10.1016/j.jdin.2021.03.002.
8. Szepietowska M, Stefaniak AA, Krajewski PK, Matusiak L. Females may have less severe acne, but they suffer more: a prospective cross-sectional study on psychosocial consequences in 104 consecutive Polish acne patients. J Clin Med. 2024;13(1):4. doi: 10.3390/jcm13010004.
9. Damoulaki E, Sioutis D, Georgiadi EP, Trakakis E, Mastorakos G, Katoulis A, et al. The association of glucose metabolism disorders and acne in women with polycystic ovary syndrome (PCOS). In Vivo. 2025;39(4):2219-2227. doi: 10.21873/invivo.14017.
10. Gratton R, Del Vecchio C, Zupin L, Crovella S. Unraveling the role of sex hormones on keratinocyte functions in human inflammatory skin diseases. Int J Mol Sci. 2022;23(6):3132. doi: 10.3390/ijms23063132.
11. Rao A, Douglas SC, Hall JM. Endocrine disrupting chemicals, hormone receptors, and acne vulgaris: a connecting hypothesis. Cells. 2021;10(6):1439. doi: 10.3390/cells10061439.
12. Del Rosso JQ, Kircik L. The cutaneous effects of androgens and androgen-mediated sebum production and their pathophysiologic and therapeutic importance in acne vulgaris. J Dermatolog Treat. 2024;35(1):2298878. doi: 10.1080/09546634.2023.2298878.
13. Condrò G, Guerini M, Castello M, Perugini P. Acne vulgaris, atopic dermatitis and rosacea: the role of the skin microbiota-a review. Biomedicines. 2022;10(10):2523. doi: 10.3390/biomedicines10102523.
14. Dréno B, Dagnelie MA, Khammari A, Corvec S. The skin microbiome: a new actor in inflammatory acne. Am J Clin Dermatol. 2020;21(Suppl 1):18-24. doi: 10.1007/s40257-020-00531-1.
15. Cavallo I, Sivori F, Truglio M, De Maio F, Lucantoni F, Cardinali G, et al. Skin dysbiosis and Cutibacterium acnes biofilm in inflammatory acne lesions of adolescents. Sci Rep. 2022;12(1):21104. doi: 10.1038/s41598-022-25436-3.
16. Lephart ED, Naftolin F. Menopause and the skin: old favorites and new innovations in cosmeceuticals for estrogen-deficient skin. Dermatol Ther (Heidelb). 2021;11(1):53-69. doi: 10.1007/s13555-020-00468-7.
17. Wilkinson HN, Hardman MJ. The role of estrogen in cutaneous ageing and repair. Maturitas. 2017;103:60-64. doi: 10.1016/j.maturitas.2017.06.026.
18. Pondeljak N, Lugović-Mihić L. Stress-induced interaction of skin immune cells, hormones, and neurotransmitters. Clin Ther. 2020;42(5):757-770. doi: 10.1016/j.clinthera.2020.03.008.
19. Chałubek A, Faruga-Lewicka W, Kardas M. The role of stress, circadian rhythm and hormonal changes in acne tarda. Aesthet Cosmetol Med. 2022;11(4):131-136. doi: 10.52336/acm.2022.020.
20. Ambalal SM. Metabolic syndrome and skin: interactions and implications. Indian J Dermatol. 2022;67(2):138-145. doi: 10.4103/ijd.ijd_155_21.
21. Sadowska-Przytocka A, Gruszczyńska M, Ostałowska A, Antosik P, Czarnecka-Operacz M, Adamski Z, et al. Insulin resistance in the course of acne-literature review. Postepy Dermatol Alergol. 2022;39(2):231-238. doi: 10.5114/ada.2021.107101.
22. Faro B, Silva-Ferraz B, Faro A. Acne, self-esteem, and mental health: a scoping review. Psychol Health Med. 2026;31(1):50-68. doi: 10.1080/13548506.2025.2465655.
23. Gruszczyńska M, Sadowska-Przytocka A, Szybiak W, Więckowska B, Lacka K. Insulin resistance in patients with acne vulgaris. Biomedicines. 2023;11(8):2294. doi: 10.3390/biomedicines11082294.
24. Szefler L, Szybiak-Skora W, Sadowska-Przytocka A, Zaba R, Wieckowska B, Lacka K. Metformin therapy for acne vulgaris: a meta-analysis. Pharmaceuticals (Basel). 2024;17(6):728. doi: 10.3390/ph17060728.
25. Och A, Och M, Nowak R, Podgórska D, Podgórski R. Berberine, a herbal metabolite in the metabolic syndrome: the risk factors, course, and consequences of the disease. Molecules. 2022;27(4):1351. doi: 10.3390/molecules27041351.
26. Zeichner JA, Baldwin HE, Cook-Bolden FE, Eichenfield LF, Fallon-Friedlander S, Rodriguez DA. Emerging issues in adult female acne. J Clin Aesthet Dermatol. 2017;10(1):37-46. PMID: 28210380; PMCID: PMC5300732.
27. Smith CA, Gosnell E, Karatas TB, Deitelzweig C, Collins EMB, Yeung H. Hormonal therapies for acne: a comprehensive update for dermatologists. Dermatol Ther (Heidelb). 2025;15(1):45-59. doi: 10.1007/s13555-024-01324-8.

28. Borzyszkowska D, Niedzielska M, Kozłowski M, Brodowska A, Przepiera A, Malczyk-Matysiak K, et al. Evaluation of hormonal factors in acne vulgaris and the course of acne vulgaris treatment with contraceptive-based therapies in young adult women. Cells. 2022;11(24):4078. doi: 10.3390/cells11244078.
29. Tommasino N, Annunziata MC, Potestio L, Napolitano M. Efficacy and safety of hormonal therapies for acne: a narrative review. Clin Cosmet Investig Dermatol. 2025;18:3331-3337. doi: 10.2147/CCID.S574341.
30. Reynolds RV, Yeung H, Cheng CE, Cook-Bolden F, Desai SR, Druby KM, et al. Guidelines of care for the management of acne vulgaris. J Am Acad Dermatol. 2024;90(5):1006.e1-1006.e30. doi: 10.1016/j.jaad.2023.12.017.
31. Szymańska K, et al. The gut-skin axis: the role of intestinal microbiota in acne, psoriasis and atopic dermatitis: a narrative review. J Educ Health Sport. 2025;83. doi: 10.12775/JEHS.2025.83.66771.
32. Zhu S, Chen H, He B, Zhang Y, Li P, Kuang J. Gut microbiota dysbiosis in polycystic ovary syndrome: focus on diet, probiotics, and traditional Chinese medicine. Front Microbiol. 2025;16:1659783. doi: 10.3389/fmicb.2025.1659783.
33. Bal Bayazıtlı EC, Aksoy Saraç G, Uzdoğan A, Acar O, Karaman HB, Külhan A, et al. Association between altered gut microbiota and acne vulgaris: a comparative study of trimethylamine N-oxide levels in patients and healthy controls. Dermatol Pract Concept. 2025;15(4):5486. doi: 10.5826/dpc.1504a5486.
34. Damoulaki E, Sioutis D, Sarli V, Trakakis E, Mastorakos G, Katoulis A, et al. Polycystic ovary syndrome-associated acne: the interplay of hyperandrogenism, insulin resistance, and therapeutic strategies. Cureus. 2025;17(11):e98103. doi: 10.7759/cureus.98103.

Article submitted: **2026-04-07**
Acceptance for publication: **2026-05-13**