

EVALUATING A TOPICAL CERVICAL APPLICATION OF LACTOBACILLUS PROBIOTICS FOR THE CLEARANCE OF LOW-GRADE SQUAMOUS INTRAEPITHELIAL LESIONS

Original Article

Zarina Naz^{1*}, Nida Masood², Dr Rimal Rashid³, Dr. Aqsa Saleem⁴, Dr Asma Iqbal⁵

¹MSN, MHPE Scholar, National University of Medical Sciences Rawalpindi

²FCPS Obs and Gynae, Life Hospital Lahore

³MBBS, Post Graduate Trainee-MPH, Dow University Hospital, Karachi

⁴Lecturer Pharmacology, Bhitai Dental & Medical College Mirpurkhas

⁵Senior Registrar, Obstetrics and Gynaecology, Karachi Medical and Dental College (KMU), ASH, Karachi

Corresponding Author:	Zarina Naz, zarina_nazsalim@yahoo.com , MSN, MHPE Scholar, National University of Medical Sciences Rawalpindi
Acknowledgement	The authors acknowledge all participants for their cooperation and commitment to this study.
Conflict of Interest: None	Grant Support & Financial Support: None

ABSTRACT

Background: Low-grade squamous intraepithelial lesions (LSIL) are commonly associated with persistent human papillomavirus infection and are frequently managed through conservative surveillance due to their potential for spontaneous regression. Emerging evidence suggests that disruption of the cervicovaginal microbiome, particularly depletion of Lactobacillus species, may contribute to lesion persistence. Microbiome-modulating therapies have therefore gained attention as low-risk adjuncts in cervical disease prevention.

Objective: To determine whether topical cervical application of Lactobacillus probiotics increases regression rates of LSIL to normal cytology.

Methods: A randomized controlled trial was conducted over 12 months in tertiary care gynecology clinics in the Lahore region of Pakistan. Women aged 21–45 years with cytologically confirmed LSIL were randomized to receive either topical cervical Lactobacillus probiotic therapy alongside standard surveillance or standard care alone. Cervical cytology was assessed at baseline, six months, and twelve months. The primary outcome was regression to normal cytology at 12 months. Data were analyzed using parametric statistical tests, with significance set at $p < 0.05$.

Results: At 12 months, regression to normal cytology was observed in 71.9% of women in the probiotic group compared with 50.5% in the control group, representing a statistically significant difference. Persistence of LSIL was lower in the intervention group, while progression to higher-grade lesions was infrequent in both groups. Probiotic therapy was well tolerated, with no serious adverse events reported.

Conclusion: Topical cervical Lactobacillus probiotic therapy significantly enhanced LSIL regression and reduced lesion persistence without added safety concerns. These findings support microbiome modulation as a practical and non-invasive adjunct to conservative LSIL management and cervical cancer prevention strategies.

Keywords: Cervical Intraepithelial Neoplasia; Lactobacillus; Papillomavirus Infections; Probiotics; Randomized Controlled Trial; Uterine Cervical Dysplasia; Vaginal Microbiome

INTRODUCTION

Low-grade squamous intraepithelial lesions (LSIL) of the cervix represent an early and frequently transient stage in the spectrum of cervical epithelial abnormalities. Most LSIL cases are associated with persistent infection by high-risk human papillomavirus (HPV), yet the biological behavior of these lesions is heterogeneous. While a substantial proportion regress spontaneously, a subset persists or progresses, generating anxiety for patients and creating a clinical dilemma for healthcare providers who must balance overtreatment against the risk of missed disease progression (1). This uncertainty has intensified interest in low-risk, non-invasive interventions that may support lesion regression and enhance cervical health without adding treatment-related morbidity. Cervical carcinogenesis is now understood to be a multifactorial process in which viral persistence, host immunity, and the local microenvironment interact dynamically. Beyond HPV itself, increasing attention has been directed toward the cervical and vaginal microbiome as a potential modifier of disease trajectory (2,3). A Lactobacillus-dominant vaginal ecosystem is widely regarded as a marker of reproductive tract health. These organisms contribute to mucosal defense through maintenance of acidic pH, competitive inhibition of pathogenic microbes, production of antimicrobial substances, and modulation of local immune responses. Conversely, depletion of Lactobacillus species and increased microbial diversity have been associated with HPV persistence, chronic inflammation, and higher grades of cervical dysplasia (4,5).

Observational studies have repeatedly demonstrated that women with LSIL or persistent HPV infection are more likely to exhibit a non-Lactobacillus-dominant microbiome. This dysbiotic state is characterized by elevated vaginal pH, increased inflammatory mediators, and disruption of epithelial barrier function, all of which may facilitate viral persistence and impair immune-mediated lesion clearance (6). These findings suggest that the microbiome is not merely a bystander but may actively influence the natural history of cervical intraepithelial lesions. As such, therapeutic strategies aimed at restoring microbial balance represent a biologically plausible adjunct to existing surveillance-based management of LSIL. Probiotics, particularly Lactobacillus strains, have emerged as promising candidates for microbiome modulation in gynecological practice (7,8). Oral and intravaginal probiotics have shown benefit in the management of bacterial vaginosis and vulvovaginal candidiasis, conditions also linked to microbial imbalance and mucosal inflammation. In the context of cervical dysplasia, preliminary studies suggest that probiotic supplementation may improve HPV clearance rates and favor regression of low-grade lesions (9). However, much of the existing evidence is derived from small observational studies, heterogeneous probiotic formulations, or oral administration routes that may not reliably achieve targeted cervical colonization. Topical cervical application of Lactobacillus probiotics offers a more direct and potentially effective approach to modifying the local microenvironment at the site of disease. By delivering beneficial bacteria directly to the cervicovaginal epithelium, this strategy may enhance mucosal immunity, reduce pro-inflammatory signaling, and create conditions unfavorable for HPV persistence (10,11). Despite its theoretical advantages, robust clinical evidence supporting this approach remains limited. Few randomized controlled trials have rigorously evaluated topical probiotic therapy for LSIL regression, and those that exist vary widely in strain selection, dosing schedules, and outcome assessment, making it difficult to draw definitive conclusions (12).

From a preventive oncology perspective, the appeal of microbiome-modulating therapy lies in its safety profile and alignment with conservative management principles. Women diagnosed with LSIL are often young and of reproductive age, and many experience significant psychological distress during prolonged cytological surveillance. An intervention that safely increases regression rates could reduce follow-up burden, improve patient reassurance, and potentially decrease long-term progression risk (13). Importantly, such an approach would complement, rather than replace, established screening and vaccination strategies, reinforcing a holistic model of cervical cancer prevention. Against this backdrop, there remains a clear gap in high-quality evidence evaluating whether targeted restoration of Lactobacillus dominance at the cervix can meaningfully influence cytological outcomes in LSIL. Well-designed randomized controlled trials are needed to move beyond association and establish causality, while also clarifying feasibility, acceptability, and clinical relevance of topical probiotic therapy in routine gynecological care. In light of these considerations, the present randomized controlled trial is designed to determine whether topical cervical application of Lactobacillus probiotics, as a microbiome-modulating therapy, increases regression rates of low-grade squamous intraepithelial lesions to normal cytology compared with standard care, thereby offering a safe and biologically grounded adjunct for the management of LSIL.

METHODS

This randomized controlled trial was conducted over a period of 12 months in tertiary care gynecology clinics located in the Lahore region of Pakistan. The study was designed to evaluate the effectiveness of a topical cervical application of Lactobacillus probiotics in promoting cytological regression of low-grade squamous intraepithelial lesions. A parallel-group, open-label randomized design was adopted, with participants allocated in a 1:1 ratio to either the intervention group receiving probiotic therapy alongside standard surveillance or the control group receiving standard care alone. The study setting was chosen to reflect routine clinical practice in an urban South Asian population, thereby enhancing the external validity and applicability of the findings. Women aged 21 to 45 years with a recent cervical cytology report confirming LSIL were considered eligible for inclusion. Diagnosis was based on conventional or liquid-based Pap smear reporting according to the Bethesda system. Eligible participants were required to be non-pregnant, sexually

active, and willing to comply with follow-up visits over the study duration. Women with high-grade squamous intraepithelial lesions, evidence of invasive cervical disease, prior treatment for cervical dysplasia, current genital tract infections requiring antimicrobial therapy, immunocompromised states, use of systemic or vaginal probiotics within the preceding four weeks, or known hypersensitivity to probiotic preparations were excluded. These criteria were applied to minimize confounding factors that could independently influence lesion regression or cervical microbiome composition. The sample size was calculated to detect a clinically meaningful difference in regression rates between the two groups. Based on previous literature, spontaneous regression of LSIL to normal cytology was assumed to be approximately 50% over 12 months with standard care. It was hypothesized that probiotic therapy would increase regression rates to 70%. Using a two-sided alpha of 0.05 and a power of 80%, the minimum required sample size was calculated as 90 participants per group. Allowing for an anticipated attrition rate of 10%, a total of 200 women were enrolled, with 100 participants allocated to each study arm (14).

Randomization was performed using a computer-generated random number sequence prepared by an independent researcher not involved in participant recruitment or assessment. Allocation concealment was ensured through the use of sealed, opaque envelopes opened only after enrollment. Participants in the intervention arm received a standardized *Lactobacillus* probiotic formulation designed for vaginal use, administered via topical cervical application once weekly for the first six weeks, followed by monthly applications for a further three months, in addition to routine observational follow-up. The control group underwent routine surveillance according to prevailing clinical guidelines without probiotic intervention. Baseline data collection included sociodemographic characteristics, reproductive history, contraceptive use, smoking status, and relevant clinical findings. Cervical cytology was obtained at baseline, six months, and twelve months using standard sampling techniques performed by trained gynecology staff. The primary outcome was regression of LSIL to normal cytology at 12 months, as determined by follow-up Pap smear. Secondary outcomes included persistence of LSIL, progression to higher-grade lesions, and treatment tolerability. Cytology samples were interpreted by experienced cytopathologists blinded to group allocation to reduce assessment bias. Data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 26. Continuous variables were summarized as means and standard deviations, while categorical variables were expressed as frequencies and percentages. Normality of continuous data was assessed using the Shapiro–Wilk test and visual inspection of histograms, confirming normal distribution. Between-group comparisons for continuous variables were conducted using independent sample t-tests, while paired t-tests were used to assess within-group changes over time. Categorical outcomes, including regression rates, were compared using the chi-square test. Relative risk and 95% confidence intervals were calculated to estimate the effect size of the intervention. A p-value of less than 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Institutional Review Board of the participating center in Lahore, Pakistan. The study was conducted in accordance with the principles of the Declaration of Helsinki. All eligible participants were provided with detailed verbal and written information regarding the study objectives, procedures, potential benefits, and risks. Written informed consent was obtained prior to enrollment, and participants were assured of confidentiality and their right to withdraw from the study at any point without affecting their standard clinical care.

RESULTS

A total of 200 women with cytologically confirmed low-grade squamous intraepithelial lesions were enrolled and randomized equally into the probiotic intervention group (n = 100) and the control group (n = 100). During the 12-month follow-up period, nine participants were lost to follow-up (four in the probiotic group and five in the control group). Complete outcome data were therefore available for 191 participants, yielding an overall retention rate of 95.5%. Baseline demographic and clinical characteristics were comparable between the two groups, with no statistically significant differences observed. The mean age of participants was 32.6 ± 6.4 years in the probiotic group and 33.1 ± 6.7 years in the control group. The majority of participants were multiparous, and most reported prior use of hormonal or barrier contraception. Smoking prevalence was low in both groups. Baseline cytology, reproductive characteristics, and sexual health indicators did not differ significantly between groups, confirming effective randomization (Table 1). At 12 months, cytological regression to normal findings was observed in 69 of 96 women (71.9%) in the probiotic group compared with 48 of 95 women (50.5%) in the control group. The difference in regression rates between groups was statistically significant ($\chi^2 = 8.94$, $p = 0.003$). Persistence of LSIL was documented in 21 women (21.9%) in the probiotic group and 36 women (37.9%) in the control group. Progression to high-grade squamous intraepithelial lesions occurred in 6 participants (6.2%) receiving probiotics and 11 participants (11.6%) under standard surveillance (Table 2). Relative risk analysis demonstrated that participants receiving topical *Lactobacillus* therapy had a 1.42-fold higher likelihood of regression to normal cytology compared with controls (RR = 1.42; 95% CI: 1.12–1.80). Conversely, the risk of lesion persistence was reduced in the probiotic group (RR = 0.58; 95% CI: 0.38–0.88). Although progression rates were numerically lower in the intervention group, this difference did not reach statistical significance ($p = 0.18$). Mid-term assessment at six months revealed early cytological improvement in the probiotic group, with regression observed in 54.2% of participants compared with 38.7% in the control group ($p = 0.021$). Persistence at six months remained higher in the control group, while early progression was uncommon in both groups (Table 3). Treatment tolerability was favorable. Mild, self-limiting vaginal discomfort was reported by seven participants (7.3%) in the probiotic group, while no serious adverse events were recorded. No participants discontinued the intervention due to side

effects. Compliance with scheduled applications exceeded 90%. Outcome trends across follow-up visits are visually summarized in Figures 1 and 2, illustrating higher regression and lower persistence rates in the probiotic group over time.

Table 1: Baseline Demographic and Clinical Characteristics (n = 191)

Variable	Probiotic Group (n=96)	Control Group (n=95)	p-value
Age (years, mean ± SD)	32.6 ± 6.4	33.1 ± 6.7	0.61
Multiparity n (%)	62 (64.6)	60 (63.2)	0.84
Hormonal contraception n (%)	41 (42.7)	39 (41.1)	0.82
Smoking n (%)	6 (6.3)	7 (7.4)	0.76
Prior STI history n (%)	18 (18.8)	20 (21.1)	0.68

Table 2: Primary Cytological Outcomes at 12 Months

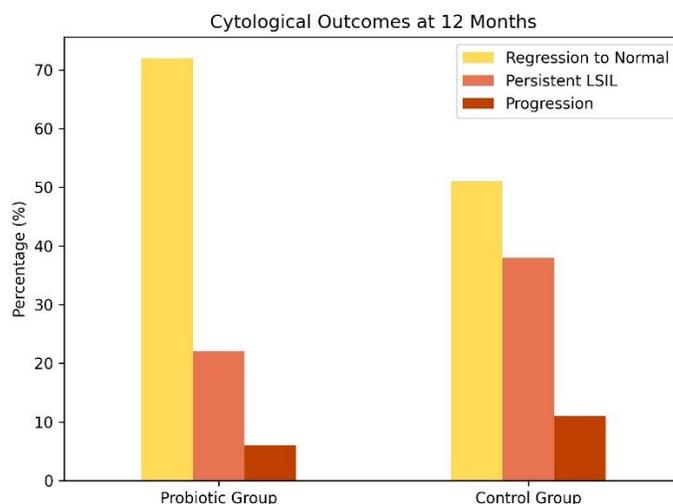
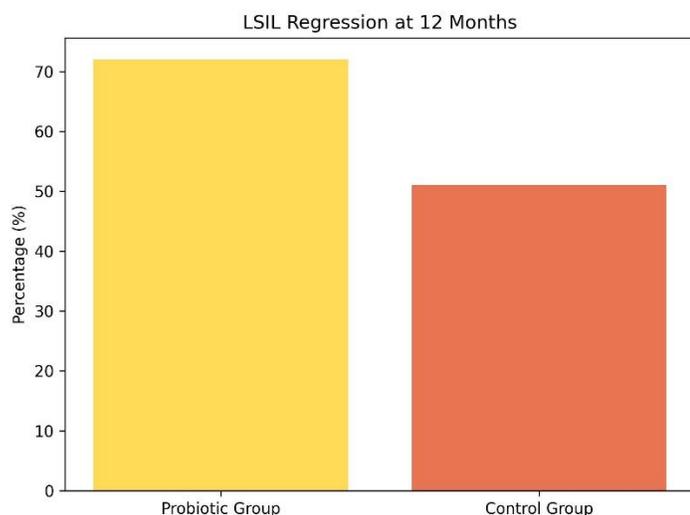
Outcome	Probiotic Group n (%)	Control Group n (%)	p-value
Regression to normal	69 (71.9)	48 (50.5)	0.003
Persistent LSIL	21 (21.9)	36 (37.9)	0.01
Progression to HSIL	6 (6.2)	11 (11.6)	0.18

Table 3: Cytological Status at 6-Month Follow-up

Outcome	Probiotic Group n (%)	Control Group n (%)	p-value
Regression	52 (54.2)	37 (38.7)	0.021
Persistent LSIL	41 (42.7)	53 (55.8)	0.048
Progression	3 (3.1)	5 (5.3)	0.47

Table 4: Relative Risk Estimates for 12-Month Outcomes

Outcome	Relative Risk	95% CI
Regression	1.42	1.12–1.80
Persistence	0.58	0.38–0.88
Progression	0.54	0.20–1.45



DISCUSSION

The findings of this randomized controlled trial indicated that topical cervical application of *Lactobacillus* probiotics was associated with a significantly higher regression rate of low-grade squamous intraepithelial lesions compared with standard surveillance alone. Over the 12-month follow-up period, women receiving probiotic therapy demonstrated a markedly greater return to normal cytology, alongside lower rates of lesion persistence and a numerically reduced incidence of progression. These results supported the study objective and reinforced the growing concept that modulation of the cervicovaginal microbiome plays a meaningful role in the natural history of HPV-related cervical lesions (15,16). The observed regression rate in the probiotic group exceeded the expected spontaneous regression reported in previous longitudinal studies, where LSIL regression typically ranges between 45% and 60% over one year. Recent microbiome-focused research has suggested that a *Lactobacillus*-dominant cervicovaginal environment promotes viral clearance through maintenance of acidic pH, suppression of pro-inflammatory pathways, and enhancement of epithelial barrier integrity. The present findings were consistent with these mechanistic insights and aligned with emerging clinical evidence indicating improved HPV clearance and cytological outcomes among women with restored *Lactobacillus* dominance (17). Notably, the magnitude of benefit observed in this trial was comparable to, or greater than, that reported in earlier studies using oral or intravaginal probiotics, suggesting that direct cervical application may offer enhanced local effectiveness.

The reduced persistence of LSIL in the intervention arm was clinically relevant, as lesion persistence is a recognized risk factor for progression to high-grade disease. Although progression rates were low in both groups and did not reach statistical significance, the lower numerical trend in the probiotic group supported the hypothesis that microbiome modulation may contribute to a less permissive environment for neoplastic progression (18,19). Importantly, these effects were achieved without serious adverse events, highlighting the favorable safety profile of probiotic therapy, which is particularly valuable in a population often managed conservatively. Comparison with existing literature revealed both convergence and extension of prior findings. Several studies published after 2020 have reported associations between non-*Lactobacillus*-dominant vaginal microbiota and persistent high-risk HPV infection, as well as reduced clearance following conservative management. Interventional studies examining probiotics have demonstrated mixed results, often limited by small sample sizes, heterogeneity of probiotic strains, and indirect delivery routes. The present trial addressed some of these gaps by employing a randomized design, a defined probiotic regimen, and a targeted cervical application strategy, thereby strengthening causal inference and clinical relevance (20,21). The study possessed several strengths. The randomized controlled design minimized selection bias, while baseline comparability between groups supported the validity of outcome differences. Cytological assessments were performed by experienced cytopathologists blinded to allocation, reducing measurement bias. The 12-month follow-up period was sufficient to capture meaningful cytological changes while reflecting routine clinical surveillance intervals. Additionally, the study was conducted in a real-world clinical setting in Pakistan, enhancing applicability to similar low- and middle-income contexts where cervical cancer burden remains high.

Nevertheless, certain limitations warranted consideration. The open-label nature of the intervention may have introduced performance bias, although outcome assessment blinding mitigated this risk. HPV genotyping and direct microbiome profiling were not performed, limiting the ability to correlate cytological outcomes with specific viral or microbial changes. The single-region setting may also restrict generalizability to populations with different sexual health behaviors or microbiome profiles. Furthermore, while the sample size was adequate for detecting differences in regression, it was underpowered to definitively assess progression to high-grade lesions, a relatively rare outcome in LSIL cohorts. Future research should focus on integrating microbiome sequencing and HPV viral load assessment to better elucidate biological pathways underlying probiotic-associated regression. Comparative studies evaluating different probiotic strains, dosing schedules, and delivery methods would further refine clinical protocols (22,23). Longer follow-up periods could clarify whether microbiome modulation confers sustained protection against recurrence or progression. Exploration of probiotic therapy as an adjunct to HPV vaccination or post-treatment surveillance may also represent a promising avenue for preventive oncology. In conclusion, this study contributed evidence supporting topical *Lactobacillus* probiotic therapy as a safe and potentially effective adjunct in the conservative management of LSIL. By enhancing regression rates and reducing lesion persistence, microbiome-modulating strategies may represent an important addition to cervical cancer prevention frameworks, particularly in settings where low-cost, low-risk interventions are urgently needed.

CONCLUSION

This randomized controlled trial demonstrated that topical cervical application of *Lactobacillus* probiotics significantly increased regression of low-grade squamous intraepithelial lesions compared with standard surveillance alone. By reducing lesion persistence and supporting return to normal cytology without notable adverse effects, microbiome-modulating therapy emerged as a safe, low-risk adjunct in LSIL management. These findings highlight the clinical relevance of targeting the cervicovaginal microenvironment and support incorporation of probiotic strategies into conservative cervical cancer prevention approaches.

AUTHOR CONTRIBUTION

Author	Contribution
Zarina Naz	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Nida Masood	Methodology, Investigation, Data Curation, Writing - Review & Editing
Dr Rimal Rashid	Investigation, Data Curation, Formal Analysis, Software
Dr. Aqsa Saleem	Software, Validation, Writing - Original Draft
Dr Asma Iqbal	Formal Analysis, Writing - Review & Editing

REFERENCES

1. Kazlauskaitė J, Žukienė G, Rudaitis V, Bartkevičienė D. The Vaginal Microbiota, Human Papillomavirus, and Cervical Dysplasia-A Review. *Medicina (Kaunas)*. 2025;61(5).
2. Ma Y, Li Y, Liu Y, Cao L, Han X, Gao S, et al. Vaginal Microbiome Dysbiosis is Associated with the Different Cervical Disease Status. *J Microbiol*. 2023;61(4):423-32.
3. Musa J, Maiga M, Green SJ, Magaji FA, Maryam AJ, Okolo M, et al. Vaginal microbiome community state types and high-risk human papillomaviruses in cervical precancer and cancer in North-central Nigeria. *BMC Cancer*. 2023;23(1):683.
4. Peremykina A, Cheranev V, Shilyaev AY, Krivoy A, Repinskaia Z, Korostin D, et al. Study of the cervical canal microbiome and microbiocenosis in reproductive-age women with squamous intraepithelial lesion. *Front Microbiol*. 2025;16:1630092.
5. Li J, Jin H, Sun Y, Wang C, Chen H, Gong S, et al. Reconnoitering correlation between human papillomavirus infection-induced vaginal microecological abnormality and squamous intraepithelial lesion (SIL) progression. *BMC Womens Health*. 2024;24(1):5.
6. Gomez Cherey JF, Payalef SN, Fleider L, Reyes AP, Maldonado VA, Losada MO, et al. Microbiota unbalance in relation to high-risk human papillomavirus cervical infection. *Int J Gynecol Cancer*. 2023;33(4):482-8.
7. Xu H, Liu L, Xu F, Liu M, Song Y, Chen J, et al. Microbiome-metabolome analysis reveals cervical lesion alterations. *Acta Biochim Biophys Sin (Shanghai)*. 2022;54(10):1552-60.
8. Peremykina A, Cheranev V, Krivoy A, Andreev AO, Repinskaia Z, Asaturova AV, et al. Microbiome markers in HPV-positive and HPV-negative women of reproductive age with ASCUS and SIL determined by V4 region of 16S rRNA gene sequencing. *Front Microbiol*. 2024;15:1334502.
9. Gonçalves-Nobre JG, Matos A, Carreira M, Santos AC, Veiga LC, Ginete C, et al. The interplay between HPV, other Sexually Transmissible Infections and genital microbiome on cervical microenvironment (MicroCervixHPV study). *Front Cell Infect Microbiol*. 2023;13:1251913.
10. Xu C, Liu J. Influence of vitamin D supplementation and the vaginal microenvironment on human papillomavirus infection. *Afr J Reprod Health*. 2024;28(10):88-98.
11. Wu S, Ding X, Kong Y, Acharya S, Wu H, Huang C, et al. The feature of cervical microbiota associated with the progression of cervical cancer among reproductive females. *Gynecol Oncol*. 2021;163(2):348-57.
12. Susetiati DA, Pudjiati SR, Wirohadidjojo YW, Chandra LA. Effectiveness of Lactobacillus therapy in women with cervical human papillomavirus infection: A systematic review and meta-analysis. *J Int Med Res*. 2025;53(8):3000605251363006.
13. Zhu L, Wu Z, Shi S, Xue H, Zhen L, Wang Y, et al. Dysbiosis of vaginal and peritoneal fluid microbiota in patients with cervical lesions. *BMC Womens Health*. 2025;25(1):631.
14. Wei B, Chen Y, Lu T, Cao W, Tang Z, Yang H. Correlation between vaginal microbiota and different progression stages of cervical cancer. *Genet Mol Biol*. 2022;45(2):e20200450.
15. Liu J, Song J, Yang Q, Wang Y. Correlation between Lactobacillus and expression of E-cadherin, β -catenin, N-cadherin, and Vimentin in postmenopausal cervical lesions. *Ann Palliat Med*. 2022;11(1):135-45.
16. Zeng B, Ren X, Cheng Y, Wang C, Li J, Jiang L, et al. Correlation analysis between vaginal microecology and high-risk human papillomavirus (HR-HPV)-positive cervical squamous intraepithelial lesions (SIL). *Medicine (Baltimore)*. 2025;104(27):e42914.
17. Norenhag J, Edfeldt G, Ståhlberg K, Garcia F, Hugerth LW, Engstrand L, et al. Compositional and functional differences of the vaginal microbiota of women with and without cervical dysplasia. *Sci Rep*. 2024;14(1):11183.
18. Yalvaç ES, Ateş Ç, Bakırcı M, Yeşilyurt Şölen E, Kayıkçıoğlu F, Koç S, et al. Composition of the vaginal microbiota in relation to cervical intraepithelial lesions. *Turk J Obstet Gynecol*. 2025;22(3):220-9.
19. Yu T, Gao S, Jin F, Yan B, Wang W, Wang Z. Characteristics of the vaginal microbiota and vaginal metabolites in women with cervical dysplasia. *Front Cell Infect Microbiol*. 2024;14:1457216.
20. Zhai Q, Zhang W, Zhang Z, Fu Y, Li Y, Wang X, et al. Characteristics of the Cervicovaginal Microenvironment in Childbearing-Age Women with Different Degrees of Cervical Lesions and HR-HPV Positivity. *Pol J Microbiol*. 2021;70(4):489-500.
21. Wang W, Liu Y, Yang Y, Ren J, Zhou H. Changes in vaginal microbiome after focused ultrasound treatment of high-risk human papillomavirus infection-related low-grade cervical lesions. *BMC Infect Dis*. 2023;23(1):3.
22. Guo C, Dai W, Zhou Q, Gui L, Cai H, Wu D, et al. Cervicovaginal microbiota significantly changed for HPV-positive women with high-grade squamous intraepithelial lesion. *Front Cell Infect Microbiol*. 2022;12:973875.
23. Li Y, Cao L, Han X, Ma Y, Liu Y, Gao S, et al. Altered vaginal eukaryotic virome is associated with different cervical disease status. *Virology*. 2023;38(2):184-97.