IJPST
Indonesian Journal of Pharmaceutical Science and Technology

Research Article
Vol. 13 No. 2 (2026): 289-296
https://doi.org/10.24198/ijpst.v13i2.71044

Effect of Curcumin Nanoliposomal Formulation on Cyclin E1 Expression and Cell Migration in HeLa Cells

Subandi Subandi[1], Resti Zulhaijah[2*], and Loeki E. Fitri[3]
[1]Department of Midwifery, Faculty of Medicine, Universitas Brawijaya, Jl. Veteran, Malang 65145, Indonesia
[2]Master Program of Midwifery, Faculty of Medicine, Universitas Brawijaya, Jl. Veteran, Malang 65145 Malang, Indonesia
[3]Department of Clinical Parasitology, Faculty of Medicine, Universitas Brawijaya, Jl. Veteran, Malang 65145, Indonesia

Abstract
Cervical cancer remains a major cause of female mortality worldwide and ranks as the second-leading cause of cancer-related death among women in Indonesia, associated with Human Papillomavirus infection. HPV-driven oncogenesis disrupts cell-cycle regulation through Cyclin E1 upregulation and promotes cell migration, thereby accelerating tumor progression. Curcumin exhibits antitumor activity, but poor solubility and bioavailability limit its clinical use. Curcumin nanoliposomal formulations have been investigated to address these limitations. This in vitro study used a post-test-only control group design to evaluate a curcumin nanoliposomal formulation in HeLa cervical cancer cells. Cells received the formulations at 100, 150, and 200 µg/mL, while cisplatin 5 µg/mL served as the positive control. Cyclin E1 expression was assessed by indirect immunofluorescence and quantified using ImageJ, whereas cell migration was evaluated by scratch wound healing assay at 0 and 24 hours. Curcumin nanoliposomal formulations significantly reduced Cyclin E1 expression (p=0.006), particularly at 150 µg/mL (p=0.016) and 200 µg/mL (p=0.034). Wound closure decreased from 19.28% in the negative control to 3.42% at 200 µg/mL, although post hoc analysis showed no significant difference between treatment groups and negative control. These findings suggest that the curcumin nanoliposomal formulation warrants further validation as a potential adjunctive therapy.

Keywords: cell migration, cervical cancer, curcumin nanoliposomal formulation, Cyclin E1, HeLa cells

Article History:
Submitted 14 June 2026
Revised 04 July 2026
Accepted 13 July 2026
Published 20 July 2026

*Corresponding author:
restizulhaijah@student.ub.ac.id

Citation:
Subandi S, Zulhaijah R, Fitri LE. Effect of Curcumin Nanoliposomal Formulation on Cyclin E1 Expression and Cell Migration in HeLa Cells. Indonesian Journal of Pharmaceutical Science and Technology. 2026: 13 (2), 289-296.

Pengaruh Formulasi Nanoliposomal Kurkumin terhadap Ekspresi Cyclin E1 dan Migrasi Sel HeLa

Abstrak
Kanker serviks merupakan penyebab utama kematian perempuan di dunia dan menempati urutan kedua sebagai penyebab kematian akibat kanker pada perempuan di Indonesia, terkait dengan infeksi Human Papillomavirus (HPV). Onkogenesis akibat HPV mengganggu regulasi siklus sel melalui peningkatan ekspresi Cyclin E1 serta mendorong migrasi sel, sehingga mempercepat progresi tumor. Kurkumin memiliki aktivitas antitumor, tetapi kelarutan dan bioavailabilitasnya yang rendah membatasi penerapan klinis. Formulasi nanoliposomal kurkumin dikembangkan untuk meningkatkan karakteristik farmasetiknya, meskipun efektivitasnya masih memerlukan evaluasi lebih lanjut. Penelitian in vitro ini menggunakan desain post-test-only control group pada sel kanker serviks HeLa. Sel diberi formulasi nanoliposomal kurkumin dengan konsentrasi 100, 150, dan 200 µg/mL, sedangkan cisplatin 5 µg/mL digunakan sebagai kontrol positif. Ekspresi Cyclin E1 diamati menggunakan imunofluoresensi dan dikuantifikasi dengan ImageJ, sedangkan migrasi sel dinilai melalui scratch wound healing assay pada jam ke-0 dan ke-24. Formulasi nanoliposomal kurkumin secara signifikan menurunkan ekspresi Cyclin E1 (p=0,006), terutama pada dosis 150 µg/mL (p=0,016) dan 200 µg/mL (p=0,034). Penutupan area migrasi menurun dari 19,28% pada kontrol negatif menjadi 3,42% pada dosis 200 µg/mL, meskipun analisis post hoc tidak menunjukkan perbedaan bermakna antara kelompok perlakuan dan kontrol negatif. Temuan ini menunjukkan bahwa formulasi nanoliposomal kurkumin memerlukan penelitian lebih lanjut sebagai terapi adjuvan potensial.

Kata Kunci: Cyclin E1, kanker serviks, migrasi sel, nanoliposomal kurkumin, sel HeLa

1. Introduction

Cervical cancer remains one of the leading causes of cancer-related mortality among women worldwide. According to GLOBOCAN 2022, cervical cancer ranks eighth among all cancers globally, with 662,301 new cases and 348,874 deaths reported in 2022. The burden is disproportionately high in Asia, which accounts for approximately 60% of global cervical cancer incidence, followed by Africa and Latin America. In Indonesia, cervical cancer is the second most common cancer among women after breast cancer, with 36,964 new cases and 20,708 deaths recorded in 2022, representing approximately 9.0% of all cancer cases in the country.[1]

Persistent infection with high-risk human papillomavirus (HPV), particularly types 16 and 18, is the primary cause of cervical cancer. Its burden is further increased by socioeconomic disparities, limited screening access, and delayed diagnosis.[2,3] The HPV E6 and E7 oncoproteins disrupt cell-cycle regulation by promoting p53 degradation and retinoblastoma protein inactivation, respectively, resulting in uncontrolled cellular proliferation.[4]

Cyclin E1 is closely involved in the regulation of the G1/S cell-cycle transition, a process that is frequently disrupted in HPV-associated cervical carcinogenesis. In HPV-positive cervical cancer, the E7 oncoprotein inactivates the retinoblastoma protein, leading to the release of E2F transcription factors and subsequent activation of S-phase-related genes, including Cyclin E1.[5,6] Therefore, Cyclin E1 was used in this study to represent cell-cycle progression associated with HPV-driven oncogenic activity. Compared with general proliferation markers such as Ki-67 and PCNA, Cyclin E1 more specifically reflects E2F-mediated cell-cycle progression following retinoblastoma protein inactivation. Its overexpression has also been associated with increased cellular proliferation and has been proposed as a biomarker of high-risk cervical lesions.[4,6]

Beyond uncontrolled proliferation, cervical cancer progression is also driven by enhanced cell migration and metastatic spread, which are associated with significantly poorer survival outcomes, particularly in patients with hematogenous metastasis or involvement of multiple organ sites.[7,8] This highlights the importance of targeting both proliferative and migratory mechanisms in therapeutic development. Current treatments include surgery, radiotherapy, and chemotherapy; however, their use may be limited by adverse effects, drug resistance, and treatment costs.[6] Curcumin, the principal bioactive polyphenol from *Curcuma longa*, has been reported to exhibit antitumor, anti-inflammatory, and antioxidant properties.[9] Nevertheless, its clinical application is restricted by poor aqueous solubility, rapid metabolism and low bioavailability.[10]

Nanoliposomal curcumin formulations have been investigated as delivery systems that may improve curcumin stability, solubility, and cellular delivery; however, these properties require formulation-specific validation.[11,12] Although cisplatin combined with nanocurcumin has been reported to reduce Cyclin E1 expression in HeLa cells,[13] the effects of Curcumin nanoliposomal formulations alone on Cyclin E1 expression and cell migration remain unclear. This study is a continuation of previous nanocurcumin formulation work, in which the curcumin nanoliposomal formulation was prepared from *Curcuma longa* rhizome extract. Therefore, the present study focused on evaluating the biological effects of this formulation on Cyclin E1 expression and migration-related behavior in HeLa cervical cancer cells.

2. Materials and Method

2.1. Materials

The curcumin nanoliposomal formulation used in this study was obtained from a previous formulation study conducted at the Pharmacy Laboratory, Universitas Brawijaya. HeLa cells (ATCC CCL-2, passage 45) were obtained from the Biomedical Laboratory, Faculty of Medicine, Universitas Brawijaya. Cell-culture reagents included RPMI-1640 medium (Sigma-Aldrich, USA) supplemented with 10% fetal bovine serum (Biowest, France) and 1% penicillin–streptomycin (Gibco, USA), trypsin–EDTA, 4% paraformaldehyde, 0.1% Triton X-100, and 1% bovine serum albumin. Immunofluorescence reagents included PE-conjugated Cyclin E1 polyclonal antibody (bs-0573R-PE; Bioss, USA), DAPI (Sigma-Aldrich, USA), and cisplatin (Kalbe Farma, Indonesia).

2.2. Methods

2.2.1. Source and Characterization of Curcumin Nanoliposomal Formulation

The curcumin nanoliposomal formulation used in this study was obtained as a prepared formulation from a previous study conducted at the Pharmacy Laboratory, Universitas Brawijaya.[13] The formulation was prepared from an ethanolic extract of turmeric rhizomes (*Curcuma longa* L.) obtained from Materia Medika, Indonesia. In the previous study, the rhizomes were extracted using 96% ethanol by Soxhlet extraction at 60°C for 8 h, followed by hexane extraction, drying, and crystallization with isopropyl alcohol.

The nanoliposomal formulation was prepared using the thin-film hydration method, in which curcumin extract, soy phosphatidylcholine, cholesterol, and Tween-80 were dissolved in chloroform, followed by solvent evaporation, hydration with PBS-Tween-80, and probe sonication. The exact quantitative ratio of each formulation component was not re-determined in the present biological study because the formulation was obtained as a prepared formulation from previous work.

Particle size was analyzed using a particle size analyzer (Shimadzu SALD-7500nano, Japan). Additional physicochemical characterization was performed using a Zetasizer (Malvern Panalytical, UK) to determine the hydrodynamic diameter, polydispersity index (PDI), and zeta potential at 25°C. HPLC analysis was used to confirm the presence of curcumin as the main marker compound in the formulation; however, the formulation was not prepared from isolated or purified curcumin as a single compound. Encapsulation efficiency, drug loading, morphology, release profile, and stability were not evaluated in the present study.

2.2.2. Cell Culture

HeLa cells (ATCC CCL-2, passage 45) were obtained from the Biomedical Laboratory, Faculty of Medicine, Universitas Brawijaya. Cell line identity was confirmed based on procurement from certified biobank (ATCC CCL-2). Mycoplasma testing was not performed during the study period. The same passage number was used throughout the experiment to maintain consistency. Cells were cultured in RPMI-1640 medium (Sigma-Aldrich, USA) supplemented with 10% FBS (Biowest, France) and 1% penicillin–streptomycin (Gibco, USA) at 37°C in a humidified 5% CO_2 atmosphere. The medium was replaced every 1–2 days, and cells were harvested using trypsin–EDTA.

2.2.3. Observation of Cyclin E1 by Immunofluorescence Assay

HeLa cells were seeded in 96-well plates and assigned to five groups: untreated control, cisplatin 5 µg/mL, and curcumin nanoliposomal formulation at 100, 150, and 200 µg/mL. The treatment concentrations referred to the prepared curcumin nanoliposomal formulation used in this study. After 24 h of treatment, cells were washed with PBS, fixed with 4% paraformaldehyde for 15 min, and permeabilized with 0.1% Triton X-100 for 10 min. Following blocking with 1% BSA for 1 h, cells were incubated with PE-conjugated Cyclin E1 polyclonal antibody (bs-0573R-PE; Bioss, USA) for 30 min in the dark. Nuclei were counterstained with DAPI, and fluorescence images were acquired using an Olympus IX73 microscope. Cyclin E1 fluorescence intensity was quantified using ImageJ.

2.2.4. Cell Migration with Scratch Wound Healing Assay

HeLa cells were cultured in 24-well plates until confluent. A linear scratch was created using a 20–200 µL pipette tip, and cells were incubated with the respective treatments in medium containing 2% FBS. Wound images were captured at 0 and 24 h, and wound area was quantified using ImageJ. Wound closure (%) was calculated as $[(A_0 - A_t)/A_0] \times 100\%$, where A_0 represents the wound area at 0 hours and A_t represents the wound area at 24 hours.

2.2.5. Data Analysis

Data were analyzed using IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test. Normally distributed data were analyzed using one-way ANOVA followed by Tukey's post hoc test. Statistical significance was set at $p < 0.05$, and data are presented as mean ± SD.

2.2.6. Ethical Considerations

This study complied with ethical research guidelines and received approval from the Health Research Ethics Committee, Faculty of Medicine, Universitas Brawijaya, under approval number 538/EC/KEPK/12/2025.

3. Result

3.1. Characterization of the Curcumin Nanoliposomal Formulation

Particle size analysis showed an average particle size of 32 nm. DLS-based analysis showed a Z-average diameter of 130.6 nm, a peak size by intensity of 157.4 nm, a PDI of 0.1633, and a zeta potential of −10.69 mV. The difference between the particle size obtained from particle size analyzer and DLS-based Z-average may be related to differences in measurement principles and sample preparation.

3.2. Effect of Curcumin nanoliposomal formulations on Cyclin E1 Expression in HeLa Cells

Cyclin E1 expression was evaluated in HeLa cells treated with curcumin nanoliposomal formulations at 100, 150, and 200 µg/mL, alongside negative and positive control (5 µg/mL cisplatin). DAPI-stained nuclei appeared blue, whereas Cyclin E1 expression appeared red in the immunofluorescence images (Figure 1). Fluorescence intensity was quantified using ImageJ and is presented in Table 1 and Figure 2.

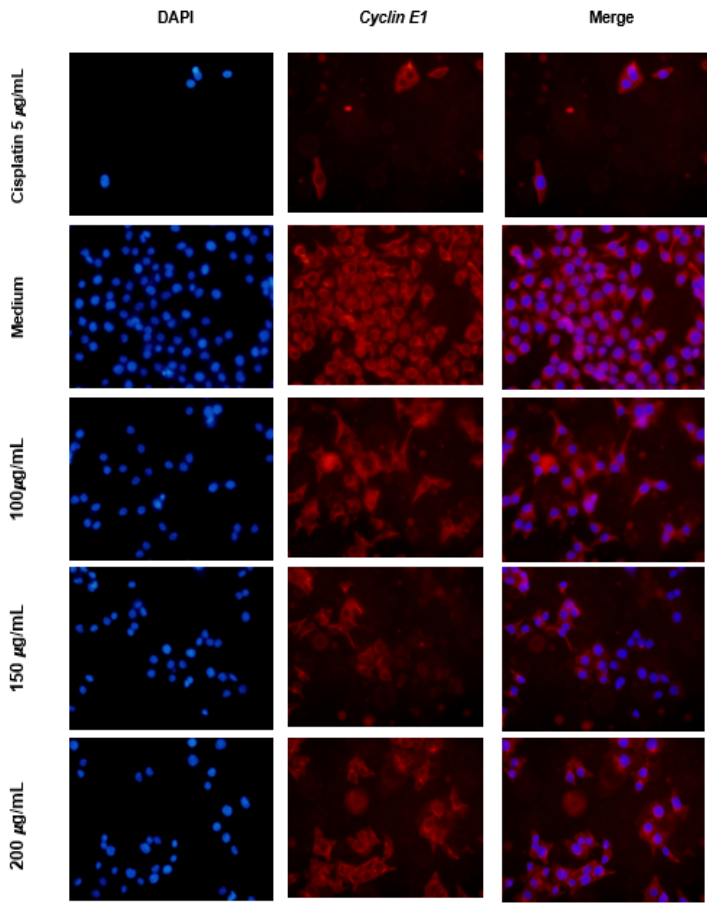

Figure 1. Immunofluorescence Images of Cyclin E1 Expression in HeLa Cells. Blue indicates DAPI-stained nuclei, red indicates Cyclin E1 expression, and merge represents the overlay of both channels. Treatment groups consisted of negative control, cisplatin 5 µg/mL, and curcumin nanoliposomal formulation at 100, 150, and 200 µg/mL.

One-way ANOVA showed significant differences among groups ($F = 7.028$; $p = 0.006$), with normally distributed data based on the Shapiro–Wilk test ($p > 0.05$). The negative control showed the highest fluorescence intensity ($39.08 \pm 8.95 \times 10^9$) and differed significantly from cisplatin ($p = 0.005$) and Curcumin nanoliposomal formulations at 150 and 200 µg/mL ($p = 0.016$ and $p = 0.034$, respectively), but not at 100 µg/mL ($p = 0.202$). No significant difference was observed between the 150 and 200 µg/mL groups ($p = 0.989$), suggesting comparable reduction in Cyclin E1 fluorescence intensity at these concentrations.

3.3. Effect of Curcumin nanoliposomal formulation on HeLa Cell Migration

To evaluate the effect of Curcumin nanoliposomal formulations on HeLa cell migration, wound closure was monitored at 0 and 24 h using an inverted microscope. Confluent HeLa monolayers were scratched and incubated with treatment in starvation medium containing 2% FBS. Cell morphology, scratch-width

Table 1. Cyclin E1 fluorescence intensity in HeLa cells.

Group	Treatment	Cyclin E1 (x10⁹ Mean ± SD)
Medium	HeLa cells without treatment	39.08 ± 8.95^{a}
Cisplatin 5 µg/mL	Cisplatin 5 µg/mL	19.17 ± 5.59^{b}
100 µg/mL	Curcumin nanoliposomal formulation 100 µg/mL	29.33 ± 2.25^{ab}
150 µg/mL	Curcumin nanoliposomal formulation 150 µg/mL	22.55 ± 3.25^{b}
200 µg/mL	Curcumin nanoliposomal formulation 200 µg/mL	24.46 ± 0.82^{b}

Note : Data are presented as mean ± SD. Different superscript letters indicate statistically significant differences between groups based on Tukey's post hoc test ($p < 0.05$).

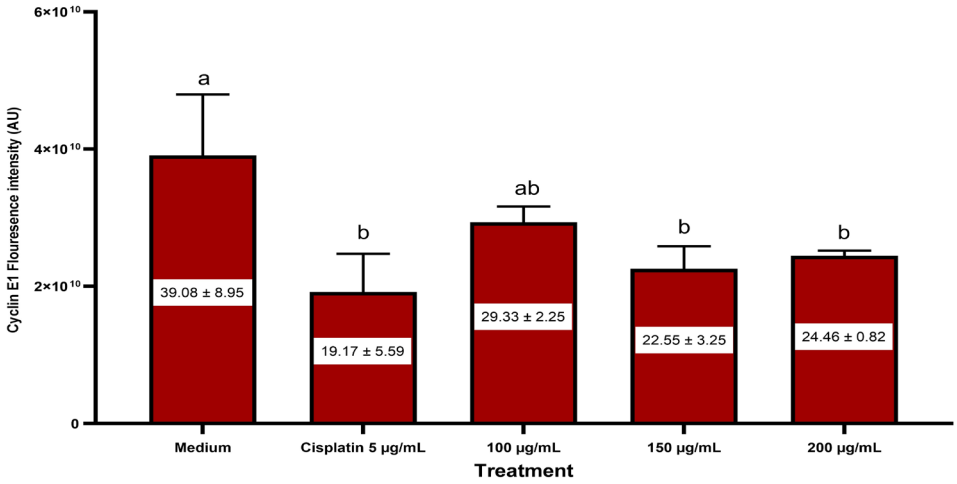

Figure 2. Cyclin E1 fluorescence intensity in HeLa cells. Data are presented as mean ± SD. $p < 0.05$ compared with the negative control.

quantification, and summarized data are presented in Figure 3-4, and Table 2.

One-way ANOVA showed significant differences among groups ($F = 28.710$; $p < 0.001$), with normally distributed data based on the Shapiro-Wilk test ($p > 0.05$). Tukey's HSD post hoc test showed that none of the curcumin nanoliposomal formulations groups differed significantly from the negative control (100 µg/mL: $p = 0.358$; 150 µg/mL: $p = 0.236$; 200 µg/mL: $p = 0.182$). Wound closure decreased descriptively with increasing formulation concentration, from 6.67 ± 4.98% at 100 µg/mL to 3.42 ± 1.81% at 200 µg/mL, compared with 19.28 ± 5.38% in the negative control. These findings indicate a descriptive reduction in wound closure; however, no statistically significant

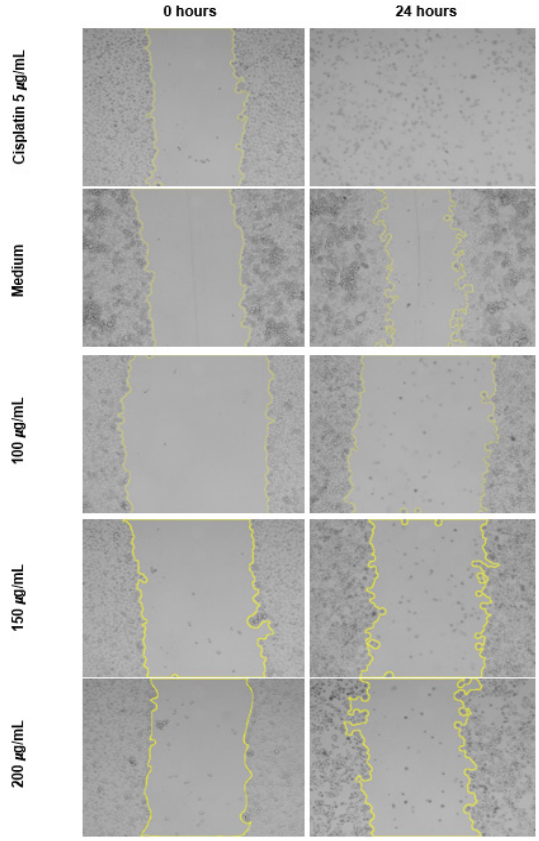

Figure 3. Scratch wound healing assay images at 0 and 24 h. Yellow lines indicate the wound edges. Treatment groups consisted of negative control, cisplatin 5 µg/mL, and curcumin nanoliposomal formulation at 100, 150, and 200 µg/mL.

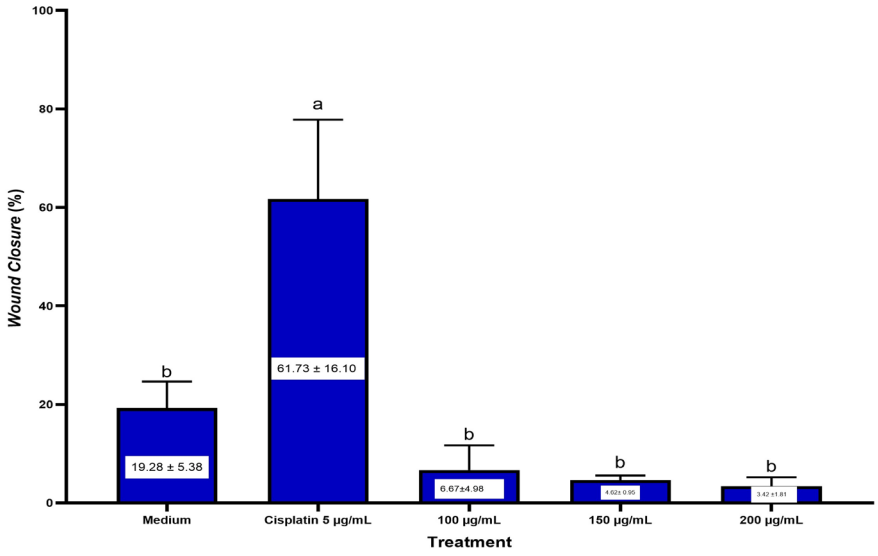

Figure 4. Wound closure percentage of HeLa cells after 24 h treatment. Data are presented as mean ± SD.

difference was observed between the treatment groups and negative control.

4. Discussion

Cyclin E1 regulates G1-to-S phase transition through its interaction with cyclin-dependent kinase 2 (CDK2).[14] In HPV-positive cervical cancer cells, the E7 oncoprotein inactivates retinoblastoma protein, releasing E2F transcription factors and promoting the expression of S-phase genes, including Cyclin E1.[15] In the present study, treatment with the curcumin nanoliposomal formulation was associated with reduced Cyclin E1 fluorescence intensity, particularly at 150 and 200 µg/mL . This finding suggests a possible effect on cell-cycle regulation in HeLa cells. However, the result should be interpreted as preliminary because additional assays such as cell viability, cell-cycle analysis, Ki-67, PCNA, BrdU/EdU incorporation or colony formation were not performed.

Previous studies have reported that curcumin can modulate Cyclin E1 expression through several regulatory pathways. Curcumin downregulated Cyclin E1 and increased p27 expression through Trop2 in bladder cancer cells, leading to cell-cycle arrest and apoptosis.[16] Curcumin nanoparticles also reduced Cyclin E1 expression in ovarian cancer cells through modulation of the NF-κB/PRL-3 pathway.[17] Other studies have suggested that curcumin may affect Notch1 and AKT signaling which may subsequently influence p21, p27 and Cyclin E1/CDK2 activity.[18] However, these pathways were not directly evaluated in the present study; therefore, they should be considered as possible mechanisms based on previous literature rather than confirmed mechanisms of the current findings.

The scratch wound healing assay showed a descriptive reduction in wound closure after treatment with the curcumin nanoliposomal formulation. However, post hoc analysis showed that the treatment groups did not differ significantly from the negative control. Therefore, the migration-related findings should be interpreted as a descriptive trend rather than statistically confirmed antimigratory activity. Moreover, wound closure may

Table 2. Wound closure percentage of HeLa cells after 24 hours treatment

Group	Treatment	Wound Closure (%) 24hr (Mean ± SD)
HeLa control cell	HeLa cells without treatment	19.28 ± 5.38^{b}
Positive Control	Cisplatin 5 µg/mL	61.73 ± 16.10^{a}
100 µg/mL	Curcumin nanoliposomal formulation 100 µg/mL	6.67 ±4.98^{b}
150 µg/mL	Curcumin nanoliposomal formulation 150 µg/mL	4.62± 0.95^{b}
200 µg/mL	Curcumin nanoliposomal formulation 200 µg/mL	3.42 ±1.81^{b}

Note : Data are presented as mean ± SD. Different superscript letters indicate statistically significant differences between groups based on Tukey's post hoc test ($p < 0.05$).

reflect cell migration, proliferation, or cell spreading. Since Cyclin E1 fluorescence intensity was reduced after treatment, the lower wound closure observed in the treatment groups may partly reflect reduced proliferative activity rather than a purely antimigratory effect.

Previous studies have suggested that curcumin may modulate pathways related to cell migration and extracellular-matrix degradation including MMP-2 downregulation and inhibition of PI3K/AKT, MAPK/ERK, focal adhesion kinase, and Rho GTPase signaling.[19–25] Curcumin has also been reported to inhibit ERO1α-mediated PI3K/AKT phosphorylation in cisplatin-resistant HeLa cells.[25] These findings may provide a possible literature-based explanation for the descriptive reduction in wound closure observed in the present study. However, these molecules were not measured experimentally; therefore, these pathways should be interpreted as possible mechanisms rather than confirmed mechanisms of the current findings.

The increased wound closure observed in the cisplatin group was unexpected. This finding suggests that cisplatin may not have functioned as an optimal positive antimigratory control under the present experimental conditions. Wound closure in this assay may be influenced by cell spreading, stress response, or proliferation-related changes rather than migration alone. Therefore, the cisplatin result should be interpreted cautiously and should not be used as the sole basis for determining antimigratory activity.

Previous studies using curcumin nanoformulations provide a useful context for interpreting the present findings. Saengkrit et al. reported that curcumin-loaded cationic liposomes showed anticancer and apoptosis-inducing activity in cervical cancer cell models, including HeLa and SiHa cells.[26] Zaman et al. demonstrated that polymeric nano-curcumin was more effective than free curcumin in inhibiting cervical cancer cell growth, inducing apoptosis, and promoting cell-cycle arrest in CaSki and SiHa cells.[27] Micellar curcumin formulations have also been reported to enhance curcumin-related biological activity, including inhibition of proliferation, migration, invasion, and colony formation in cancer cell models.[28]

Curcumin-encapsulated nanomicelles were further shown to improve cellular uptake and cytotoxicity compared with plain curcumin in cisplatin-resistant and parental cancer cells.[29] These studies suggest that nanoformulation may influence curcumin-related biological responses.[26–29] However, unlike several previous studies, the present study did not include free curcumin, empty nanocarrier controls, encapsulation efficiency, drug loading, or uptake analysis. Therefore, the observed reduction in Cyclin E1 fluorescence intensity and wound closure should be interpreted cautiously and cannot be attributed exclusively to nanoliposomal delivery.

5. Study Limitations

This study has several limitations. First, the curcumin nanoliposomal formulation was partially characterized using particle size, PDI, zeta potential, and HPLC. However, encapsulation efficiency, drug loading, TEM/SEM morphology, release profile, and stability were not evaluated in either study. Therefore, the proportion of curcumin entrapped in the nanoliposomes cannot be confirmed, and the observed biological effects cannot be exclusively attributed to nanoliposomal delivery. Second, free curcumin and empty nanoliposome control groups were not included; consequently, the observed biological effects cannot be attributed exclusively to nanoliposomal delivery. Third, this study used only one cervical cancer cell line and did not include in vivo validation, which may limit the generalizability of findings. Fourth, cell viability, apoptosis, cell-cycle analysis, Western blot, and gene expression assays were not performed; therefore, the biological interpretation should be considered preliminary. Fifth, the scratch assay cannot clearly distinguish reduced migration from reduced proliferation or cell spreading. Future studies should include comprehensive formulation characterization, appropriate formulation controls, additional biological assays, and in vivo validation to strengthen the interpretation of these findings.

6. Conclusion

This study showed that the curcumin nanoliposomal formulation was associated with reduced Cyclin E1 fluorescence intensity and lower wound closure in HeLa cells under the present experimental conditions. However, because the formulation was not fully characterized and additional biological validation was not performed, these findings should be interpreted as preliminary. Further studies are needed to validate these findings using more comprehensive formulation and biological evaluations.

Acknowledgment

The authors would like to thank Saiful Arifin and Ami Maghfironi, laboratory technicians at the Biomedical Laboratory, Faculty of Medicine, Universitas Brawijaya, for their technical support during this research.

Conflict of Interest

The authors declare no conflicts of interest

References

1. World Cancer Research Fund. Cervical cancer statistics [Internet]. London: World Cancer Research Fund; cited 2026 Jun 2. Available from: https://www.wcrf.org/preventing-cancer/cancer-statistics/cervical-cancer-statistics/
2. Asotic A, Doric M. Molecular Genetic Basis of Cervical Cancer. Int J Biomed Healthc. 2024;12(1):53. doi:10.5455/ijbh.2024.12.53-62
3. Okunade KS. Human papillomavirus and cervical cancer. J Obstet Gynaecol J Inst Obstet Gynaecol. 2020;40(5):602-608. doi:10.1080/01443615.2019.1634030
4. Garcia-Becerra N, Garcia-Becerra CA, Fernandez-Avila L, et al. Molecular and Cell Biology of Cervical Cancer. In: Cervical Cancer - Recent Advances and New Perspectives. IntechOpen; 2023. doi:10.5772/intechopen.1002395
5. Burmeister CA, Khan SF, Schäfer G, et al. Cervical cancer therapies: Current challenges and future perspectives. Tumour Virus Res. 2022;13:200238. doi:10.1016/j.tvr.2022.200238
6. Tavakolian S, Goudarzi H, Faghihloo E. Cyclin-dependent kinases and CDK inhibitors in virus-associated cancers. Infect Agent Cancer. 2020;15(1):27. doi:10.1186/s13027-020-00295-7
7. Li H, Wu X, Cheng X. Advances in diagnosis and treatment of metastatic cervical cancer. J Gynecol Oncol. 2016;27(4):e43. doi:10.3802/jgo.2016.27.e43
8. Zhang Y, Guo Y, Zhou X, Wang X, Wang X. Prognosis for different patterns of distant metastases in patients with uterine cervical cancer: a population-based analysis. J Cancer. 2020;11(6):1532-1541. doi:10.7150/jca.37390
9. Wang P, Wu Q, Peng Q, et al. Comparative analysis of the molecular mechanism of inhibiting proliferation and migration in cervical cancer HeLa cell by curcumin and resveratrol. Nat Prod Res. 2023;37(23):4032-4037. doi:10.1080/14786419.2022.2162517
10. Mundekkad D, Cho WC. Applications of Curcumin and Its Nanoforms in the Treatment of Cancer. Pharmaceutics. 2023;15(9):2223. doi:10.3390/pharmaceutics15092223
11. Elena S, Anjana S, Cat Tuong DT, et al. Curcumin's Therapeutic Potential in Ovarian Cancer: Current Insights and Future Perspectives. Food Sci Nutr. 2025;13(12):e71099. doi:10.1002/fsn3.71099
12. Karthikeyan A, Senthil N, Min T. Nanocurcumin: A Promising Candidate for Therapeutic Applications. Front Pharmacol. 2020;11:487. doi:10.3389/fphar.2020.00487
13. Subandi S, Balindra F, Gizta A, Khotimah H, Handono K. Nano Liposomal Curcumin as an Adjuvant: Enhancing Cisplatin Anticancer Effects in HeLa Cells. Sci Pharm. 2025;4(2):96-102. doi:10.58920/sciphar0402347
14. Cui J, Chen H, Chen Y, et al. Licoisoflavone A inhibits colorectal cancer cell proliferation through targeting CDK2-Cyclin E1 axis-mediated cell cycle transition. Biochem Pharmacol. 2025;240:117124. doi:10.1016/j.bcp.2025.117124
15. Zhong S, Zhang Y, Yin X, Di W. CDK7 inhibitor suppresses tumor progression through blocking the cell cycle at the G2/M phase and inhibiting transcriptional activity in cervical cancer. OncoTargets Ther. 2019;Volume 12:2137-2147. doi:10.2147/OTT.S195655
16. Zhang L, Yang G, Zhang R, et al. Curcumin inhibits cell proliferation and motility via suppression of TROP2 in bladder cancer cells. Int J Oncol. Published online May 30, 2018. doi:10.3892/ijo.2018.4423
17. Liu S, Zhou S, Wang B, Jia Z. Effects of curcumin nanoparticles on the proliferation and migration of human ovarian cancer cells assessed through the NF-κB/PRL-3 signaling pathway. Int Immunopharmacol. 2024;141:112964. doi:10.1016/j.intimp.2024.112964
18. Sha J, Li J, Wang W, et al. Curcumin induces G0/G1 arrest and apoptosis in hormone independent prostate cancer DU-145 cells by down regulating Notch signaling. Biomed Pharmacother. 2016;84:177-184. doi:10.1016/j.biopha.2016.09.037
19. Zheng F, Lu J, Wang C, Yu H, Fu Y, Ma D. Curcumin enhances ATG3-dependent autophagy and inhibits metastasis in cervical carcinoma. Cell Div. 2024;19(1):33. doi:10.1186/s13008-024-00138-6
20. Wang K, Xiao W, Zeng Q. Curcumin Inhibits Bladder Cancer by Inhibiting Invasion via AKT/MMP14 Pathway. Discov Med. 2024;36(180):71-81. doi:10.24976/Discov.Med.202436180.6
21. Wang N, Feng T, Liu X, Liu Q. Curcumin inhibits migration and invasion of non-small cell lung cancer cells through up-regulation of miR-206 and suppression of PI3K/AKT/mTOR signaling pathway. Acta Pharm. 2020;70(3):399-409. doi:10.2478/acph-2020-0029
22. Zhang H, Xu W, Li B, et al. Curcumin Promotes Cell Cycle Arrest and Inhibits Survival of Human Renal Cancer Cells by Negative Modulation of the PI3K/AKT Signaling Pathway. Cell Biochem Biophys. 2015;73(3):681-686. doi:10.1007/s12013-015-0694-5
23. Wang H, Zhang K, Liu J, et al. Curcumin Regulates Cancer Progression: Focus on ncRNAs and Molecular Signaling Pathways. Front Oncol. 2021;11. doi:10.3389/fonc.2021.660712
24. Cao L, Liu J, Zhang L, Xiao X, Li W. Curcumin inhibits H2O2-induced invasion and migration of human pancreatic cancer via suppression of the ERK/NF-κB pathway. Oncol Rep. 2016;36(4):2245-2251. doi:10.3892/or.2016.5044
25. Huang D, Baldandorj B, Odkhuu E, et al. ERO1α regulates curcumin-induced autophagy via PI3K/AKT pathway. Cancer Treat Res Commun. 2025;44:100957. doi:10.1016/j.ctarc.2025.100957
26. Saengkrit N, Saesoo S, Srinuanchai W, Phunpee S, Ruktanonchai UR. Influence of curcumin-loaded cationic liposome on anticancer activity for cervical cancer therapy. Colloids Surf B Biointerfaces. 2014;114:349-356. doi:10.1016/j.colsurfb.2013.10.005
27. Zaman MS, Chauhan N, Yallapu MM, et al. Curcumin Nanoformulation for Cervical Cancer Treatment. Sci Rep. 2016;6(1):20051. doi:10.1038/srep20051
28. Zhu WT, Liu SY, Wu L, et al. Delivery of curcumin by directed self-assembled micelles enhances therapeutic treatment of non-small-cell lung cancer. Int J Nanomedicine. 2017;12:2621-2634. doi:10.2147/IJN.S128921
29. Kumbar VM, Muddapur U, Bin Muhsinah A, et al. Curcumin-Encapsulated Nanomicelles Improve Cellular Uptake and Cytotoxicity in Cisplatin-Resistant Human Oral Cancer Cells. J Funct Biomater. 2022;13(4):158. doi:10.3390/jfb13040158