Glosains: Jurnal Sains Global Indonesia
Volume 7, Issue 3, 1-10
e_ISSN: 2798-4311
https://glosains.staiku.ac.id
DOI: doi.org/10.59784/glosains.v7i3.797

Association Between Ultrasonographic Femoral Cartilage Thickness and Kellgren–Lawrence Grade in Knee Osteoarthritis: A Cross-Sectional Study

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Article Info:

***Article history*:**
Received: May 18, 2026
Revised: June 11, 2026
Accepted: June 14, 2026

***Keywords*:**
Cartilage thickness; Knee osteoarthritis; Osteophytes; Radiography; Ultrasonography

Abstract

Background: Knee osteoarthritis (OA) is a common degenerative joint disease and a major cause of disability among older adults. Although radiography remains the standard diagnostic imaging modality, its inability to directly visualize articular cartilage limits its usefulness in evaluating structural damage. Ultrasonography (US) provides a noninvasive method for measuring cartilage thickness.

Objective: This cross-sectional study aimed to examine the association between ultrasonographically measured femoral cartilage thickness and radiographic severity based on the Kellgren–Lawrence (KL) grading system.

Methods: Primary data were collected from 104 patients, comprising 160 knees, who were recruited through consecutive sampling at PKU Muhammadiyah Bantul Hospital between December 2025 and January 2026.

Results: The Jonckheere–Terpstra trend test confirmed a significant decreasing ordinal trend in femoral cartilage thickness across increasing KL grades ($Z = -2.362$, $p = 0.018$). However, the Kruskal–Wallis omnibus test showed no statistically significant difference among the KL-grade groups ($H = 7.280$, $df = 3$, $p = 0.063$).

Conclusion: A weak but statistically significant negative correlation ($r_s = -0.185$) was observed between ultrasonographic femoral cartilage thickness and KL grade, accompanied by a significant decreasing ordinal trend. However, these findings should be interpreted cautiously because of the weak effect size, cross-sectional design, and inclusion of bilateral knee observations.

To cite this article: Prisila, E., Sukirto, N. W., Pratama, R. A., & Ramadhani, S. C. (2026). Association between ultrasonographic femoral cartilage thickness and Kellgren–Lawrence grade in knee osteoarthritis: A cross-sectional study. *Glosains: Jurnal Sains Global Indonesia*, 7(3), 1-10. https://doi.org/10.59784/glosins.v7i3.797

INTRODUCTION

Knee osteoarthritis (OA) is a highly prevalent degenerative joint disease among older adults, characterized by articular cartilage loss and extensive structural changes within the joint (Hsu et al., 2025). Its incidence is substantial; data from PKU Muhammadiyah Bantul Hospital showed that knee OA was the most common form of OA, accounting for 373 cases (64.42%) among a total of 579 patients with OA (Prisila et al., 2025). Its pathogenesis involves complex interactions among risk factors, such as age, obesity, and genetic predisposition, and mechanical stress, which

trigger inflammation and tissue degradation (Tong et al., 2022).

Clinically, knee OA is diagnosed using the American College of Rheumatology (ACR) criteria, which incorporate clinical symptoms and radiographic findings, including osteophytes (Mobasheri et al., 2023; Hellmi et al., 2021). Conventional radiography remains the most affordable and widely used imaging modality in clinical practice (Almhdie-Imjabbar et al., 2023). However, it has significant limitations because it primarily evaluates bony changes and only indirectly reflects articular cartilage damage (Zhao et al., 2021). Consequently, radiography may be less sensitive in detecting early structural changes, potentially resulting in delayed diagnosis or an inaccurate assessment of disease progression.

As an alternative, ultrasonography (US) has emerged as a valuable noninvasive, radiation-free adjunctive imaging modality for the direct evaluation of joint structures (Herrmann et al., 2021). US has demonstrated high sensitivity (92%) for detecting medial femoral cartilage damage, greater sensitivity than radiography for detecting early osteophytes Nevalainen (2023), and a strong correlation with magnetic resonance imaging (MRI) findings (Marsico et al., 2025). Beyond these technical advantages, ultrasonography permits repeated and dynamic evaluations without radiation exposure, making it particularly relevant for monitoring disease progression in resource-limited settings.

Early detection is crucial in the management of knee OA because most cartilage damage is irreversible. Early intervention may slow disease progression, reduce pain, preserve joint function, and ultimately delay or prevent the need for surgery (Brophy & Fillingham, 2022; Gibbs et al., 2023). However, the clinical application of US continues to face challenges, particularly because of its operator-dependent nature and variations in examination techniques.

Despite the growing body of evidence supporting ultrasonographic cartilage assessment, evidence from Indonesian clinical populations regarding the association between ultrasonographically measured femoral cartilage thickness and radiographic disease severity, as classified using the Kellgren–Lawrence grading system, remains limited. Population-specific differences in disease-severity distribution, patient demographics, and clinical practice settings may affect this association; therefore, findings from international populations may not be directly generalizable to Indonesian patients. Accordingly, this study aims to evaluate the association between ultrasonographic femoral cartilage thickness and the radiographic severity of knee osteoarthritis based on the Kellgren–Lawrence classification, thereby providing population-specific evidence from an Indonesian clinical cohort.

METHOD

This study used an analytical observational design with a cross-sectional approach to evaluate the association between femoral cartilage thickness measured using ultrasonography and the radiographic severity of knee osteoarthritis based on the Kellgren–Lawrence (KL) classification. The study was conducted at PKU Muhammadiyah Bantul General Hospital, Yogyakarta, Indonesia, from December 2025 to January 2026.

The study population consisted of outpatients with knee pain or suspected knee osteoarthritis who were referred from the outpatient clinic to the radiology department for knee radiography. Participants were recruited using consecutive sampling, whereby all eligible patients presenting during the study period were enrolled until the required sample size was reached. The inclusion criteria were age greater than 40 years, the presence of knee pain or suspected knee osteoarthritis, and willingness to participate, as indicated by the provision of written informed consent.

The exclusion criteria included acute knee trauma or joint infection requiring immediate treatment, a history of total knee arthroplasty (TKA), congenital structural abnormalities of the knee joint, pregnancy, and contraindications to the study procedures. A total of 104 patients, representing 152 knees, were included in the analysis. Of these, 48 patients contributed bilateral knee data, accounting for 96 knees, whereas 56 patients contributed data from one knee each, accounting for 56 knees. The analyses were performed at the knee level. Because bilateral knees from the same patient are statistically correlated, this clustering effect represents a methodological limitation that should be considered when interpreting the results.

Radiographic severity was assessed using anteroposterior knee radiographs and graded

according to the Kellgren–Lawrence classification. Ultrasonographic examinations were performed using a GE LOGIQ™ P9 ultrasound system equipped with a 12-MHz linear-array transducer. The symptomatic knee was examined with the patient in the supine position and the knee flexed to approximately 30°. The transducer was positioned transversely and perpendicular to the cartilage surface, and the minimum femoral cartilage thickness was measured in millimeters. All ultrasonographic examinations were performed by a trained radiologist to minimize measurement variability.

Descriptive statistics were used to summarize the data. The association between cartilage thickness and KL grade was analyzed using Spearman's rank correlation test. Differences in cartilage thickness across KL grades were evaluated using the Kruskal–Wallis test, whereas the Jonckheere–Terpstra test was used to assess ordinal trends. A p value of less than 0.05 was considered statistically significant.

This study was approved by the Research Ethics Committee of Universitas Ahmad Dahlan under ethical clearance number REC-UAD/01/01/11-2025/436. Written informed consent was obtained from all participants before their inclusion in the study.

Editorial note: The original numerical statement reported 160 knees; however, 96 bilateral knees plus 56 single knees equals 152 knees. This figure should be verified against the original dataset. "Total knee replacement" was also standardized to the more technically appropriate term total knee arthroplasty (TKA). No non-English terms requiring italics were identified; only the statistical symbol p was italicized according to standard scientific usage.

RESULTS AND DISCUSSION

Results

A total of 104 patients with knee osteoarthritis (OA) who met the inclusion criteria were enrolled at PKU Muhammadiyah Bantul Hospital between December 2025 and February 2026. All participants underwent knee radiography and ultrasonography (US). In total, 160 osteoarthritic knees from these 104 patients were evaluated.

The demographic characteristics of the study participants are presented at the patient level. The variables include age, sex, and the pattern of knee involvement among patients with knee OA. These data provide an overview of the participants' demographic profile and the distribution of knee involvement within the study population.

Table 1. Demographic and Clinical Characteristics of the Study Participants

Characteristic	(n = 104)	(%)
Gender		
Male	25	24.0
Female	79	76.0
Age (years)		
40 – 49	19	18.3
50 – 59	39	37.5
60 – 69	31	29.8
70 – 79	11	10.6
80 – 89	4	3.8
Knee Involvement		
Right unilateral	23	22.1
Left unilateral	25	24.1
Bilateral	56	53.8

Table 1 summarizes the demographic and clinical characteristics of the study participants. A total of 104 patients were included, with a predominance of females (76.0%) compared with males (24.0%). The participants' mean age was 59.1 ± 10.3 years, with an age range of 41–87 years. Most participants were in their fifth and sixth decades of life, and the 50–59-year age group was the most prevalent (37.5%). Bilateral knee involvement was observed in more than half of the patients (53.8%), whereas unilateral involvement affected the right knee in 22.1% and the left

knee in 24.1% of the patients.

Table 2. Distribution of Knee Osteoarthritis Severity Based on Kellgren–Lawrence Classification

Kellgren–Lawrence Classification	(n = 160)	(%)
Grade 1	26	16.3
Grade 2	75	46.9
Grade 3	51	31.9
Grade 4	8	5.0

The characteristics of osteoarthritis were further evaluated at the knee level. The assessed variables included the distribution of osteoarthritis severity according to the Kellgren–Lawrence (KL) grading system and femoral cartilage thickness measured using ultrasonography. Cartilage thickness was summarized using descriptive statistics, including the mean, median, interquartile range, and overall range.

Table 2 presents the distribution of knee osteoarthritis severity according to the Kellgren–Lawrence classification among 160 knees. Grade 2 was the most prevalent severity grade (46.9%), followed by Grade 3 (31.9%) and Grade 1 (16.3%), whereas Grade 4 represented the smallest proportion (5.0%).

Ultrasonographic measurement of femoral cartilage thickness was performed in all 160 knees included in the study. The mean femoral cartilage thickness was 1.09 ± 0.41 mm, whereas the median thickness was 1.00 mm, with an interquartile range of 0.50 mm. The measured cartilage thickness ranged from 0.20 to 2.80 mm, indicating substantial variability among the examined knees.

Table 3. Distribution of Femoral Cartilage Thickness According to Kellgren–Lawrence Classification

KL Classification (n = 160)		Cartilage Thickness			
		Mean ± SD (mm)	Median (mm)	IQR (mm)	Range (mm)
Grade 1	26	1.10 ± 0.30	1.15	0.50	0.50 – 1.80
Grade 2	75	1.18 ± 0.45	1.10	0.50	0.60 – 2.80
Grade 3	51	1.00 ± 0.45	0.9	0.50	0.50 – 2.00
Grade 4	8	0.91 ± 0.57	0.75	0.93	0.20 – 1.90

Table 3 presents the distribution of ultrasonographically measured femoral cartilage thickness across the different Kellgren–Lawrence (KL) grades. The mean cartilage thickness was 1.10 ± 0.30 mm for KL grade 1, 1.18 ± 0.45 mm for grade 2, 1.00 ± 0.45 mm for grade 3, and 0.91 ± 0.57 mm for grade 4. Similarly, the median cartilage thickness generally decreased from 1.15 mm in grade 1 to 0.75 mm in grade 4. Although the mean value was slightly higher in grade 2 than in grade 1, the overall descriptive pattern suggests a reduction in femoral cartilage thickness with increasing KL grade.

Based on these descriptive findings, a statistical analysis was conducted to assess the association between femoral cartilage thickness and the severity of knee osteoarthritis.

Table 4. Spearman Correlation Between Femoral Cartilage Thickness and KL Classification

Variable	r_s	p-value	n
Cartilage thickness and KL classification	–0,185	0.019	160

Table 4 presents the results of the Spearman rank-correlation analysis evaluating the association between femoral cartilage thickness and Kellgren–Lawrence (KL) grade. The analysis demonstrated a weak but statistically significant negative correlation between femoral cartilage thickness and KL grade ($r_s = -0.185$, $p = 0.019$), indicating that femoral cartilage thickness tends to decrease as the radiographic severity of knee osteoarthritis increases.

Table 5. Jonckheere–Terpstra Trend Analysis of Femoral Cartilage Thickness Across KL Grades

Variable	Z	p-value	n
Trend of femoral cartilage thickness across KL classification	-2,362	0.018	160

Jonckheere–Terpstra ordinal trend analysis was performed to evaluate changes in femoral cartilage thickness across increasing Kellgren–Lawrence (KL) grades. The results demonstrated a significant decreasing trend in femoral cartilage thickness as the KL grade increased ($Z = -2.362$; $p = 0.018$), indicating that cartilage thickness tends to decline with greater radiographic severity of knee osteoarthritis.

Table 6. Kruskal–Wallis Test for Femoral Cartilage Thickness Across KL Classification

Variable	H	df	p-value	n
Femoral cartilage thickness across KL classification	7,280	3	0.063	160

The Kruskal–Wallis test was performed to compare femoral cartilage thickness across the Kellgren–Lawrence (KL) grades. The analysis showed no statistically significant difference in cartilage thickness among the KL grades ($H = 7.280$, $df = 3$, $p = 0.063$). The nonsignificant Kruskal–Wallis result does not contradict the significant Jonckheere–Terpstra finding. The Kruskal–Wallis test evaluates differences among groups regardless of direction, whereas the Jonckheere–Terpstra test is specifically designed to detect monotonic ordered trends and therefore has greater statistical power when a directional hypothesis is specified a priori. Notably, the mean cartilage thickness was slightly greater in KL grade 2 (1.18 mm) than in KL grade 1 (1.10 mm). This nonmonotonic pattern may partly explain the nonsignificant omnibus test result and may reflect early cartilage swelling associated with collagen matrix disruption in early-stage osteoarthritis.

Discussion

This study investigated the relationship between femoral cartilage thickness measured using ultrasonography and the radiographic severity of knee osteoarthritis according to the Kellgren–Lawrence (KL) classification. The findings demonstrated a significant negative correlation between femoral cartilage thickness and KL grade ($r_s = -0.185$; $p = 0.019$), indicating that cartilage thickness tends to decrease as the radiographic severity of osteoarthritis increases. Trend analysis using the Jonckheere–Terpstra test further confirmed a significant decreasing trend in cartilage thickness across increasing KL grades ($p = 0.018$).

These results suggest that ultrasonographic assessment of cartilage thickness may serve as an additional tool for evaluating structural changes in knee osteoarthritis. However, given the weak magnitude of the observed correlation ($r_s = -0.185$), the findings of this study alone are insufficient to conclude that ultrasonography is a reliable complementary modality to radiographic assessment. Further studies with larger sample sizes and diagnostic-accuracy designs are needed to establish its clinical utility.

The findings of this study are consistent with those of previous studies demonstrating that ultrasonographic measurements of femoral cartilage thickness are associated with the severity of knee osteoarthritis. Articular cartilage degeneration is a hallmark of osteoarthritis and results in progressive thinning of the cartilage layer1. Ultrasonography has increasingly been recognized as an effective diagnostic technique for evaluating cartilage morphology because it enables direct visualization of the cartilage, unlike radiography, which detects only secondary changes, such as osteophyte formation and joint-space narrowing (Pane RV et al., 2026).

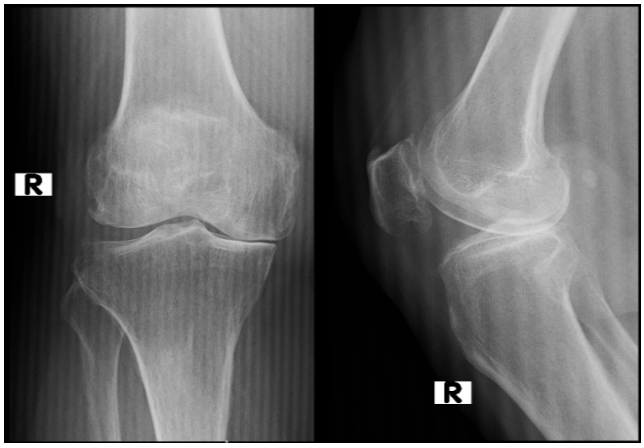

Figure 1. Antero-posterior (AP) and lateral view of knee radiograph (source: PKU Bantul General Hospital medical records)

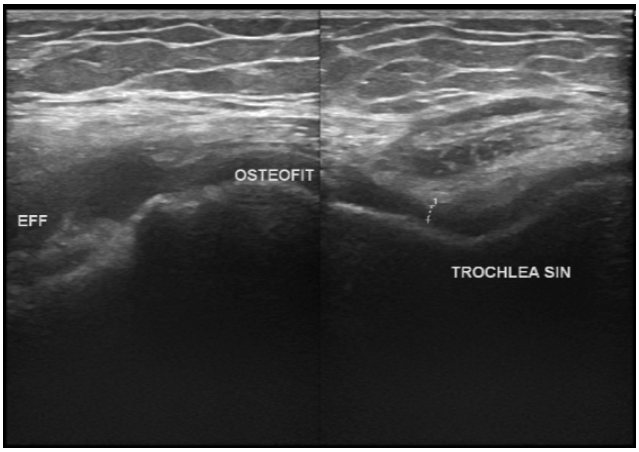

Figure 2. Ultrasonography of knee cartilage (source: PKU Bantul General Hospital medical records)

The demographic characteristics of the participants showed that most were women, who constituted 76% of the study population. This observation is consistent with epidemiological evidence indicating that the prevalence of knee osteoarthritis among postmenopausal women is higher than that among men (Curry et al., 2022). A decrease in blood estrogen levels may increase oxidative stress and promote chondrocyte degeneration in the knee joint, making women more susceptible to knee osteoarthritis than men (Gilmer G et al., 2023). The mean age of the participants was 59.1 years, with the largest proportion belonging to the 50–59-year age group. Age-related cellular senescence reduces the ability of chondrocytes to synthesize collagen and proteoglycans, resulting in progressive cartilage degeneration (Magnusson et al., 2019).

Moreover, more than half of the study population had bilateral knee osteoarthritis (54%). Bilateral disease may be associated with excessive axial loading and compensatory gait patterns. Patients experiencing pain in one knee often shift their weight to the contralateral side, potentially accelerating disease progression in the initially unaffected limb (Xu et al., 2025). Radiographic assessment revealed that most participants had KL grade 2 or grade 3 disease, indicating moderate disease severity. Early cartilage damage is usually asymptomatic because articular cartilage lacks vascular and neural innervation. Symptoms generally develop when degenerative changes affect other tissues containing nociceptors, such as the subchondral bone, menisci, and synovium (Yao et al., 2023; Hu et al., 2021).

Unlike radiography, which indirectly evaluates cartilage loss by assessing joint-space narrowing, ultrasonography allows the direct measurement of cartilage thickness. The mean femoral cartilage thickness was 1.09 mm. This value is substantially lower than the normal femoral cartilage thickness reported among healthy Indonesian adults, which ranges from 1.76 to 1.92 mm (Pane et al., 2022). The association between KL grade and cartilage thickness was statistically significant, although the strength of the association was weak. Several

pathophysiological mechanisms may explain this finding.

During the early stages of osteoarthritis, disruption of the cartilage collagen matrix increases water absorption and causes cartilage swelling, which may appear as increased cartilage thickness on ultrasonography, particularly during the transition from KL grade 1 to KL grade 2 (Salzlechner et al., 2025). In this study, one knee classified as KL grade 2 had a cartilage thickness of 2.80 mm, possibly reflecting cartilage swelling associated with disruption of the collagen matrix. Moreover, radiographic evidence of joint-space narrowing does not always correspond to cartilage loss because structural abnormalities, such as medial meniscal extrusion, may cause joint-space collapse even when the articular cartilage remains relatively well preserved (Suwal et al., 2024; Sumen et al., 2025). Osteophyte formation may also occur early in the disease process, even before substantial cartilage loss develops, as part of a compensatory response to altered joint mechanics (Kaneko H et al., 2019).

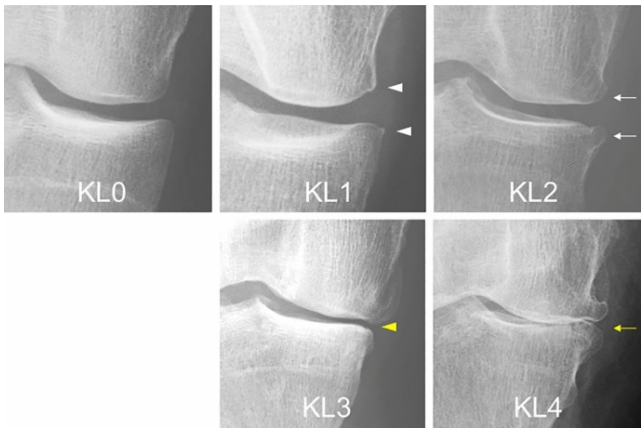

Figure 3. KL grades of knee osteoarthritis

However, the trend analysis showed that cartilage thickness progressively decreased as the KL grade increased. The median cartilage thickness gradually decreased from 1.15 mm at KL grade 1 to 0.75 mm at KL grade 4. This finding indicates progressive degenerative changes in the articular cartilage as knee osteoarthritis advances. It is consistent with the natural progression of osteoarthritis, in which cartilage degradation occurs concurrently with subchondral bone sclerosis, osteophyte formation, and joint-space narrowing, ultimately leading to irreversible structural damage (Hunter et al., 2019; Geng R et al., 2023).

From a clinical perspective, the findings of this study suggest that ultrasonographic measurement of femoral cartilage thickness may provide additional structural information in patients with knee osteoarthritis. Although radiography remains the standard imaging modality for classifying structural severity using the Kellgren–Lawrence grading system, ultrasonography enables direct visualization of the articular cartilage and may complement radiographic findings. However, because this study evaluated only the association between cartilage thickness and radiographic grade without assessing diagnostic accuracy or clinical decision-making outcomes, it would be premature to conclude that combining these imaging modalities improves clinical assessment. Further prospective studies incorporating diagnostic accuracy and clinical utility designs are required (Singh et al., 2021).

Several factors may have confounded the observed relationship between femoral cartilage thickness and Kellgren–Lawrence grade but were not controlled for in this analysis. Age-related chondrocyte senescence progressively reduces cartilage synthesis; estrogen deficiency in postmenopausal women accelerates chondrocyte degeneration; an elevated body mass index increases mechanical loading on the articular cartilage; and the specific anatomical site of ultrasonographic measurement, such as the medial or lateral femoral condyle, may yield substantially different cartilage thickness values. The absence of adjustment for these confounding factors limits the interpretation of the observed correlation. Furthermore, because 56 of the 104 patients contributed data from both knees, the assumption of statistical independence was violated. The resulting within-patient clustering may have affected the

precision of the correlation estimates and should be addressed using mixed-effects models or regression models with cluster-robust standard errors in future studies.

This study has several limitations. Its cross-sectional design precludes the determination of causal relationships between cartilage thickness and disease progression. Additionally, ultrasonographic measurement of cartilage thickness is operator-dependent and requires assessment by trained radiologists or other appropriately trained imaging specialists, which may introduce measurement variability and limit the generalizability of the findings. Future studies with larger sample sizes and longitudinal designs are needed to better characterize the relationship between ultrasonographically measured femoral cartilage thickness and the progression of knee osteoarthritis.

CONCLUSION

This study found a weak but statistically significant negative correlation between ultrasonographically measured femoral cartilage thickness and Kellgren–Lawrence (KL) grade ($r_s = -0.185$, $p = 0.019$), along with a significant decreasing ordinal trend across increasing KL grades ($Z = -2.362$, $p = 0.018$). However, the Kruskal–Wallis omnibus test did not demonstrate a statistically significant difference among the KL-grade groups ($H = 7.280$, $df = 3$, $p = 0.063$). These findings should be interpreted cautiously because of the weak effect size, cross-sectional design, small number of knees classified as KL grade 4, and statistical dependence arising from the inclusion of bilateral knee data. Ultrasonography may provide supplementary structural information for assessing knee osteoarthritis; however, its complementary clinical utility requires further evaluation in prospective diagnostic-accuracy studies employing statistical methods that account for clustering.

ACKNOWLEDGEMENT

The authors sincerely thank Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Universitas Ahmad Dahlan for providing financial support through the 2025 internal research grant program. Gratitude is also extended to PKU Muhammadiyah Bantul Hospital for facilitating data collection and supporting the implementation of this study.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the study's conception and design, data collection, analysis, and manuscript preparation. Funding for this research was provided by LPPM Universitas Ahmad Dahlan. All authors reviewed and approved the final manuscript and declare no conflict of interest.

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