ABSTRAK

Pengukuran intensitas nyeri di lingkungan klinis saat ini sebagian besar masih bersifat subjektif dan mengandalkan pelaporan mandiri pasien, sehingga berisiko memicu bias evaluasi pada populasi non-verbal. Sebagai solusi objektif, parameter otonom *Electrodermal Activity* (EDA) atau konduktansi kulit mulai banyak dieksplorasi karena keterkaitannya yang erat dengan aktivitas sistem saraf simpatis. Penelitian ini bertujuan untuk mengidentifikasi, menganalisis, dan menyintesis tantangan teknis serta peluang implementasi sistem deteksi nyeri objektif berbasis EDA melalui metode *Systematic Literature Review* (SLR) dengan mengadopsi pedoman PRISMA 2020. Penapisan literatur dilakukan secara ketat terhadap artikel-artikel orisinal bereputasi internasional dalam rentang waktu terupdate. Hasil sintesis data menunjukkan bahwa tantangan teknis utama dalam implementasi EDA klinis meliputi kerentanan yang tinggi terhadap artefak gerakan (*motion artifacts*), variabilitas kondisi biologis kulit individu, serta adanya disparitas regulasi otonom yang dipengaruhi oleh faktor gender (*female-male differences*). Di sisi lain, peluang keberhasilan teknologi ini didorong kuat oleh perkembangan algoritma pemrosesan sinyal digital modern, seperti pemanfaatan fitur diferensial (*dphEDA* dan *MTVSymp*), serta implementasi model *supervised* maupun *unsupervised machine learning* untuk otomatisasi deteksi dan eliminasi artefak gerakan. Lebih lanjut, integrasi arsitektur *deep learning* kontinu (seperti *CrossMod-Transformer*) dan penerapan kerangka kerja *Explainable Artificial Intelligence* (XAI) terbukti mampu mengatasi keterbatasan sensor tunggal sekaligus memberikan transparansi visual atas keputusan klinis model cerdas pada populasi anak-anak, dental, maupun ginekologi. Penelitian ini memberikan landasan teoritis yang kokoh bagi perancangan aplikasi *smart healthcare* masa depan berbasis *Edge AI* pada perangkat *wearable*.

Kata Kunci: Aktivitas Elektrodermal (EDA), Deteksi Nyeri, Artefak Gerakan, *Machine Learning*, *Explainable AI* (XAI).

ABSTRACT

Pain intensity measurement in clinical settings is currently predominantly subjective, relying heavily on patient self-reporting, which poses a significant risk of evaluation bias in non-verbal populations. As an objective alternative, the autonomic parameter *of Electrodermal Activity (EDA), or skin conductance, has been widely explored due to its direct link with sympathetic nervous system activity. This study aims to identify, analyze, and synthesize the technical challenges and implementation opportunities of EDA-based objective pain detection systems through a Systematic Literature Review (SLR) adhering to the PRISMA 2020 guidelines. A rigorous screening process was conducted on high-impact international original research articles up to the latest publications. The synthesized findings reveal that the primary technical challenges in clinical EDA implementation include high susceptibility to motion artifacts, individual biological variability in skin conditions, and autonomic regulation disparities influenced by gender factors (female-male differences). Conversely, implementation opportunities are strongly driven by advances in modern digital signal processing algorithms, such as the utilization of differential fitures ($dphEDA$ and $MTVSymp$), and the implementation of supervised or unsupervised machine learning models for automated motion artifact detection and elimination. Furthermore, the integration of continuous deep learning architectures (e.g., CrossMod-Transformer) and the application of Explainable Artificial Intelligence (XAI) frameworks have proven effective in overcoming single-sensor limitations while providing visual transparency for clinical decision-making in pediatric, dental, and gynecological populations. This study provides a robust theoretical foundation for designing future smart healthcare applications utilizing Edge AI on wearable devices.*

Keywords: *Electrodermal Activity (EDA), Pain Detection, Motion Artifacts, Machine Learning, Explainable AI (XAI).*