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An ODE Model for Investigating the Sleep-Pain Relationship in Sickle Cell Disease

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Abstract

Sickle cell disease (SCD) is a family of genetic blood disorders that affects over 20 million people worldwide, whose prevalent complication is pain. Pain crises in SCD are strongly linked to mortality, morbidity and increased medical costs. The study in Valrie et al. 2019 revealed a correlation between sleep and pain using patient reported sleep quality and pain in 88 pediatric SCD patients and we use this data to inform our model. Our model reflects that sickle cell pain in childhood presents as intermittent pain crises and that poor sleep quality is correlated with increased SCD pain.

In this study, we further investigated this sleep-pain connection using mathematical tools that incorporate a dynamical systems approach. Based on the results in Clifton et al 2017 and Yang et al 2019, we created an ODE model for predicting pediatric SCD pain levels based on self-reported sleep data. Our initial model captured some aspects of the pain profile but had significant discrepancies. To further explore the sleep-pain relationship, we investigated multiple strategies for implementing the effects of sleep and pain outcomes. To assess the utility of the model for capturing pain onset, we explored methods for categorizing pain and determining patient-specific sleep metrics. Our long term goal is to develop a warning system for upcoming pain events for pediatric SCD patients. This is advantageous in the digital age as noninvasive monitoring will allow physicians to treat pain crises in these patients anywhere based on personalized, data-driven recommendations.