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Development of an Interpretable AI-Assisted Framework for Contextual Interpretation of Continuous Glucose Monitoring Patterns

Jasmeet Kaur, PhD[1] · Vijay Raj Sharma, PhD[2] · Shashikant Iyengar, MBA[3]
[1] Independent Researcher, Moga, Punjab, India [2] Department of Medical Physics, University of Wisconsin–Madison, Madison, Wisconsin, USA [3] Independent Researcher, Mumbai, Maharashtra, India

ABSTRACT

Continuous glucose monitoring (CGM) provides rich temporal information on glucose dynamics; however, interpretation remains largely dependent on isolated glucose values, summary metrics, and food-related events, often overlooking the physiological context underlying observed glucose patterns. We developed an interpretable AI-assisted conceptual framework that integrates temporal CGM pattern recognition with contextual physiological information to support individualized and explainable behavioural guidance. Representative glucose behaviours, including stable profiles, dawn phenomenon, transient excursions, sustained plateaus, oscillatory variability, and recovery dynamics, were identified using rule-guided temporal analysis and interpreted alongside physiological factors such as circadian timing, sleep, physical activity, meal timing, and environmental temperature. Illustrative examples demonstrate how similar glucose values may represent different physiological processes depending on biological context. The proposed framework highlights the potential of integrating wearable-derived physiological data with explainable artificial intelligence (AI) to improve contextual interpretation, support personalized behavioural recommendations, and provide a foundation for future multimodal wearable integration in precision metabolic health.

CLINICAL MOTIVATION

Current CGM interpretation primarily focuses on glucose values and summary metrics. However, glucose regulation is influenced by multiple interacting physiological systems. Similar glucose patterns may therefore arise from different biological mechanisms, highlighting the need for contextual interpretation rather than isolated numerical analysis.

Why Context Matters

Temporal glucose patterns often provide more physiological information than single glucose values.
Circadian rhythm, sleep, physical activity, environmental temperature, and autonomic regulation all influence glucose dynamics.
Identical interventions may produce different glucose responses across individuals.
Explainable AI can integrate multimodal wearable data while maintaining transparency and clinician oversight

CONTACT
Jasmeet Kaur
Independent Researcher
Moga, Punjab, India
jasmeet48@gmail.com

METHODS & CONCEPTUAL FRAMEWORK

The proposed framework analyses post-processed CGM data using rule-guided temporal pattern recognition. Rather than interpreting isolated glucose values, it recognizes characteristic glucose behaviours and integrates contextual physiological information to support explainable behavioural guidance.

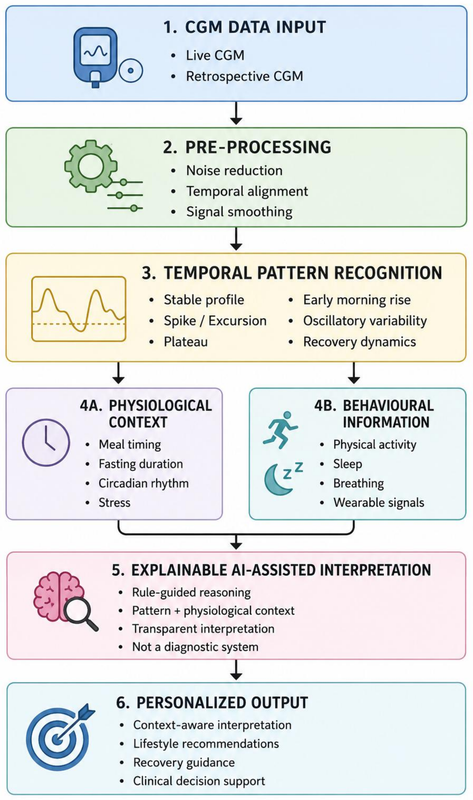


Figure 1. Conceptual framework illustrating the integration of temporal CGM pattern recognition with contextual physiological and behavioural information to enable transparent, explainable AI-assisted interpretation and individualized behavioural guidance.

REPRESENTATIVE CGM PATTERNS [Temporal Pattern Recognition (Real Healthy Volunteer)]

Representative post-processed CGM recordings from a healthy individual illustrating how temporal glucose patterns may have multiple plausible physiological explanations. These examples demonstrate the need for contextual interpretation and are presented to illustrate

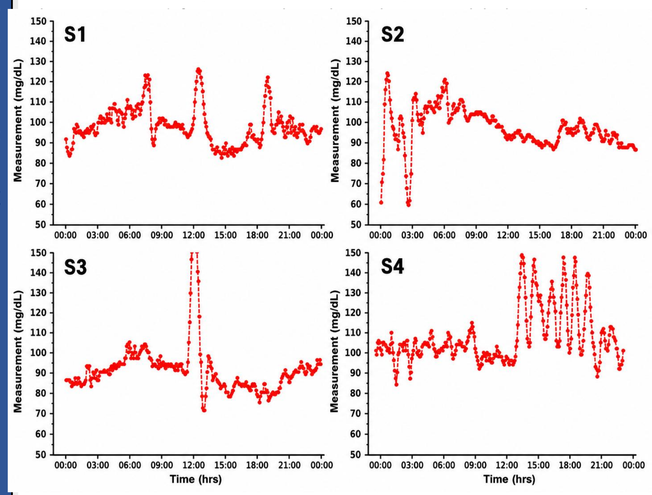


Figure 2. *Representative post-processed CGM recordings obtained from a healthy individual. The temporal glucose patterns illustrate examples of physiological variability encountered in routine practice and highlight how interpretation may be refined by incorporating contextual information such as meal timing, fasting duration, physical activity, stress, sleep, and circadian influences.*

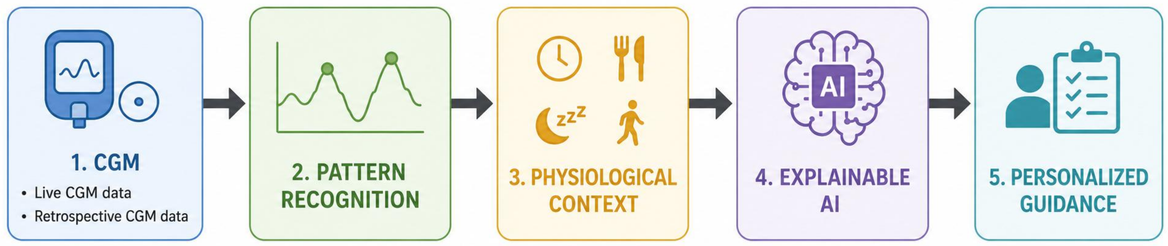
REPRESENTATIVE PATTERN	OBSERVATION	POTENTIAL PHYSIOLOGICAL CONTRIBUTORS
S1. MULTIPLE GLUCOSE EXCURSIONS	Multiple transient glucose rises followed by rapid recovery toward baseline throughout the day.	Similar glucose excursions may arise from **meal-related responses, acute psychological stress, physical activity, or combinations of these factors**. Temporal glucose patterns alone are insufficient to distinguish the underlying contributor, emphasizing the importance of contextual physiological information.
S2. EARLY-MORNING VARIABILITY (DAWN PHENOMENON)	Initial glucose fluctuations followed by an early-morning rise and relatively stable glucose concentrations during the remainder of the day.	The observed variability may reflect physiological **counter-regulatory responses, circadian influences, or other transient physiological adaptations.** Integration **of fasting duration, sleep quality, autonomic state, and meal timing** would enable a more comprehensive interpretation.
S3. TRANSIENT EXCURSION DURING PROLONGED FASTING	A pronounced glucose excursion occurred around midday before the first meal and returned rapidly to baseline.	As the participant remained in a prolonged fasting state, the excursion may represent an **acute sympathetic response to psychological or physical stress, the physiological effects of fasting, or an interaction between these factors**. The glucose response might differ under a fed state, emphasizing the importance of nutritional context.
S4. REPEATED GLUCOSE OSCILLATIONS	Multiple sequential glucose peaks and declines were observed over a relatively short period.	Although the participant reported consuming protein bars during this period, concurrent physiological factors, **including physical activity, psychological stress, circadian influences, and meal composition**, may also contribute to the observed variability. Integration of multimodal wearable data would improve differentiation between dietary and non-dietary contributors.

Identical glucose values or similar CGM patterns may arise from different physiological processes. Integrating contextual physiological information enables more transparent, explainable, and individualized interpretation than glucose values alone.

CONCLUSION

- Temporal glucose patterns should be interpreted within their physiological and behavioural context rather than as isolated glucose levels.
- The proposed explainable AI-assisted framework integrated temporal CGM dynamics with contextual physiological context information to support transparent and individualized interpretation.

This conceptual framework provides a foundation for future multimodal wearable systems capable of delivering context-aware behavioural guidance while maintaining clinician oversight.



Future Work

- Validate the framework in larger and more diverse populations.
- Integrate multimodal wearable data (HRV, respiration, sleep, physical activity) for real-time personalized metabolic insights.
- Develop prospective clinical studies to evaluate its utility in lifestyle intervention and disease management.

References
1. Ahmed A, et al. ***Use of Continuous Glucose Monitoring with Machine Learning to Identify Metabolic Subphenotypes and Inform Precision Lifestyle Changes.*** *arXiv. 2025;2511.03986v1.*
2. Klonoff DC, et al. ***Continuous Glucose Monitoring Data Analysis 2.0: Functional Data Pattern Recognition and Artificial Intelligence Applications.*** *Journal of Diabetes Science and Technology. 2025;19(6):1515–1527. doi:10.1177/19322968251353228.*

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