

Beyond Sugar: Nutrient Patterns and Dental Caries Risk in US Children Using Explainable Machine Learning

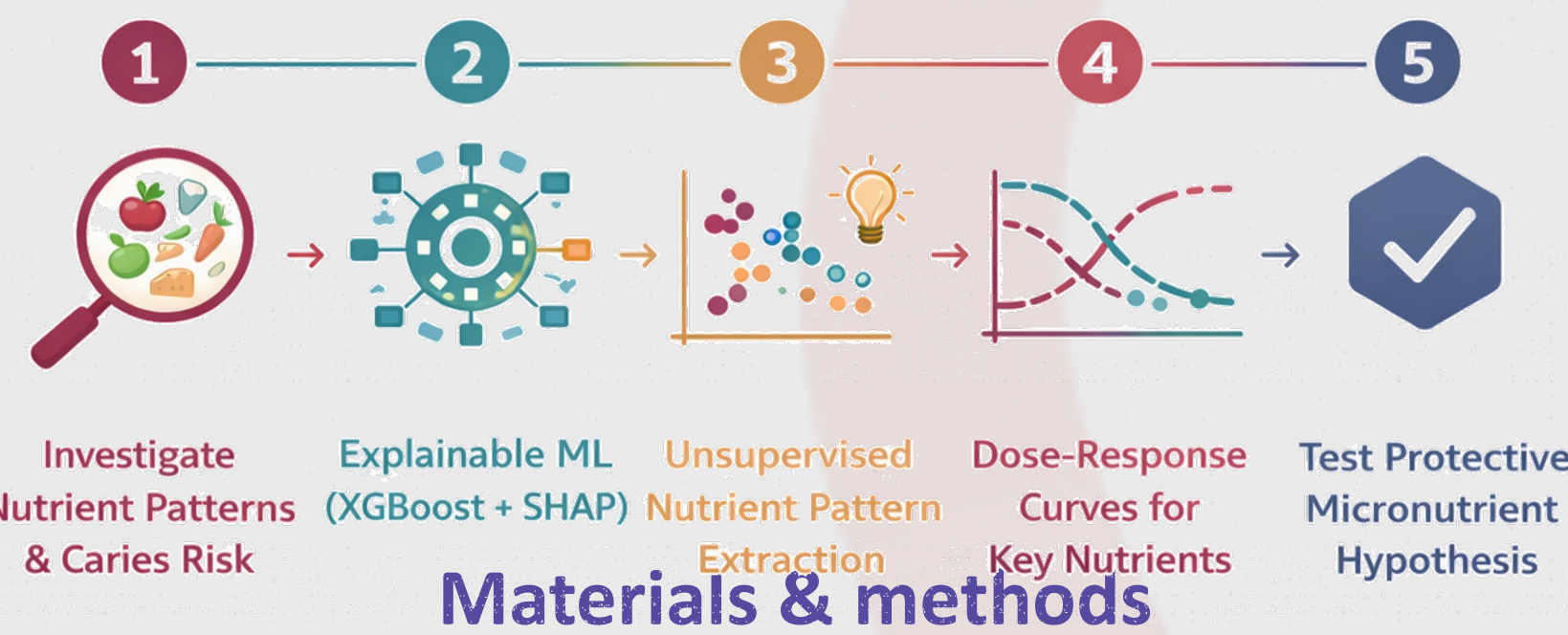
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Background

- Early Childhood Caries (ECC) affects ~514 million children globally (WHO, 2022) and remains one of the most prevalent chronic childhood diseases.
- Traditional research focuses on sugar as the primary dietary risk factor, but the protective role of other nutrients (Ca, P, Vitamin D) is underexplored.
- Machine learning combined with explainable AI (SHAP) enables deeper analysis of complex diet–caries interactions beyond simple sugar associations.

Objectives

- To identify dietary nutrient patterns (not just individual nutrients) associated with dental caries risk in US children aged 2–11 years using NHANES 2011–2018.
- To apply explainable machine learning (XGBoost + SHAP) and unsupervised pattern extraction (PCA, NMF) to determine both risk and protective dietary factors.

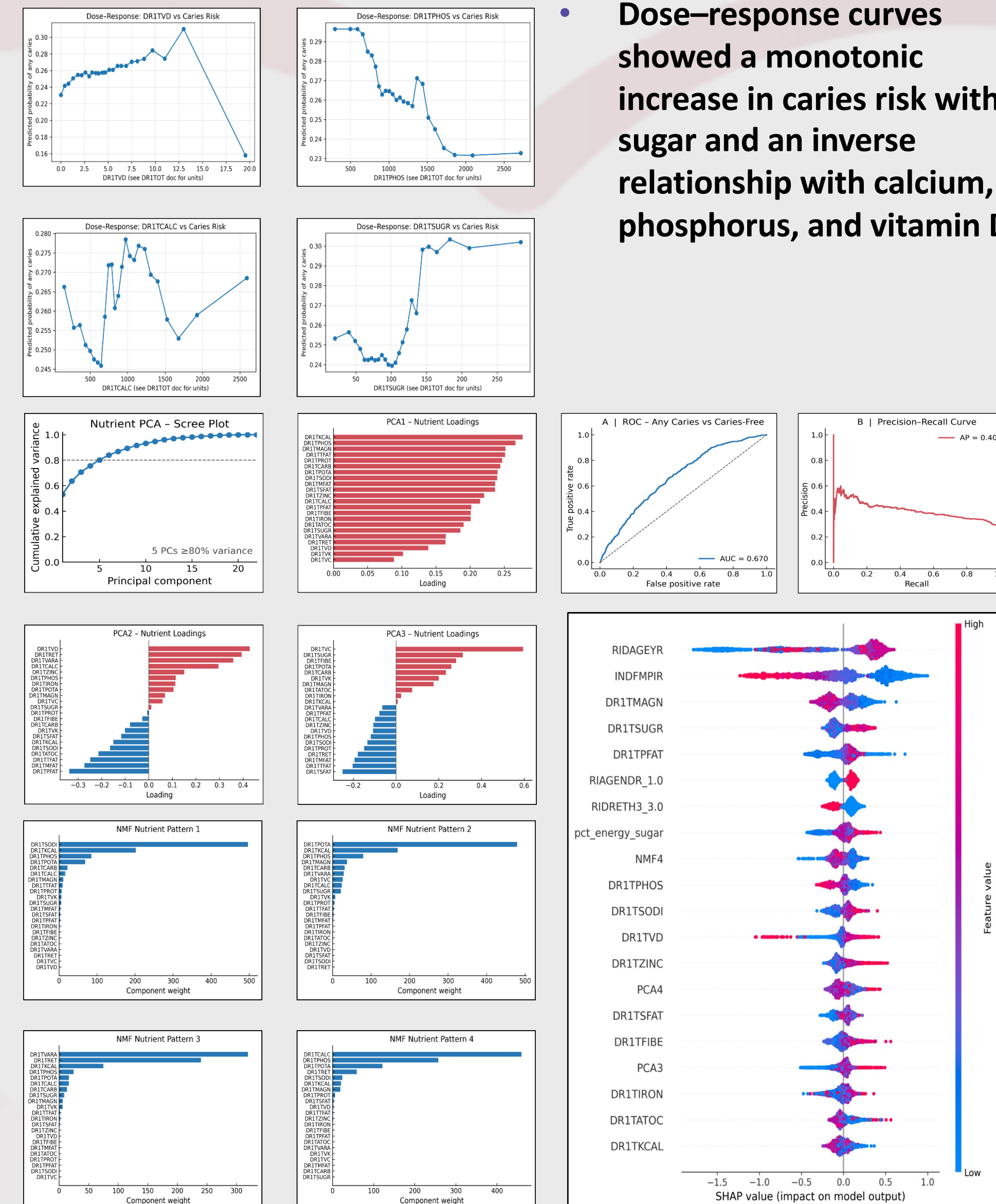


Materials & methods

- **Data:** NHANES 2011–2018 (4 cycles), children aged 2–11 with completed 24-hour dietary recall and dental examination.
- **Nutrient Patterns:** PCA and NMF used to extract broad dietary patterns from 24-hour recall data.
- **ML Model:** XGBoost classifier trained on nutrient intakes, dietary patterns, and sociodemographic covariates (age, sex, race/ethnicity, poverty-to-income ratio).
- **Interpretation:** SHAP values for feature importance and model-based dose–response curves for sugar, calcium, phosphorus, and vitamin D.

Results

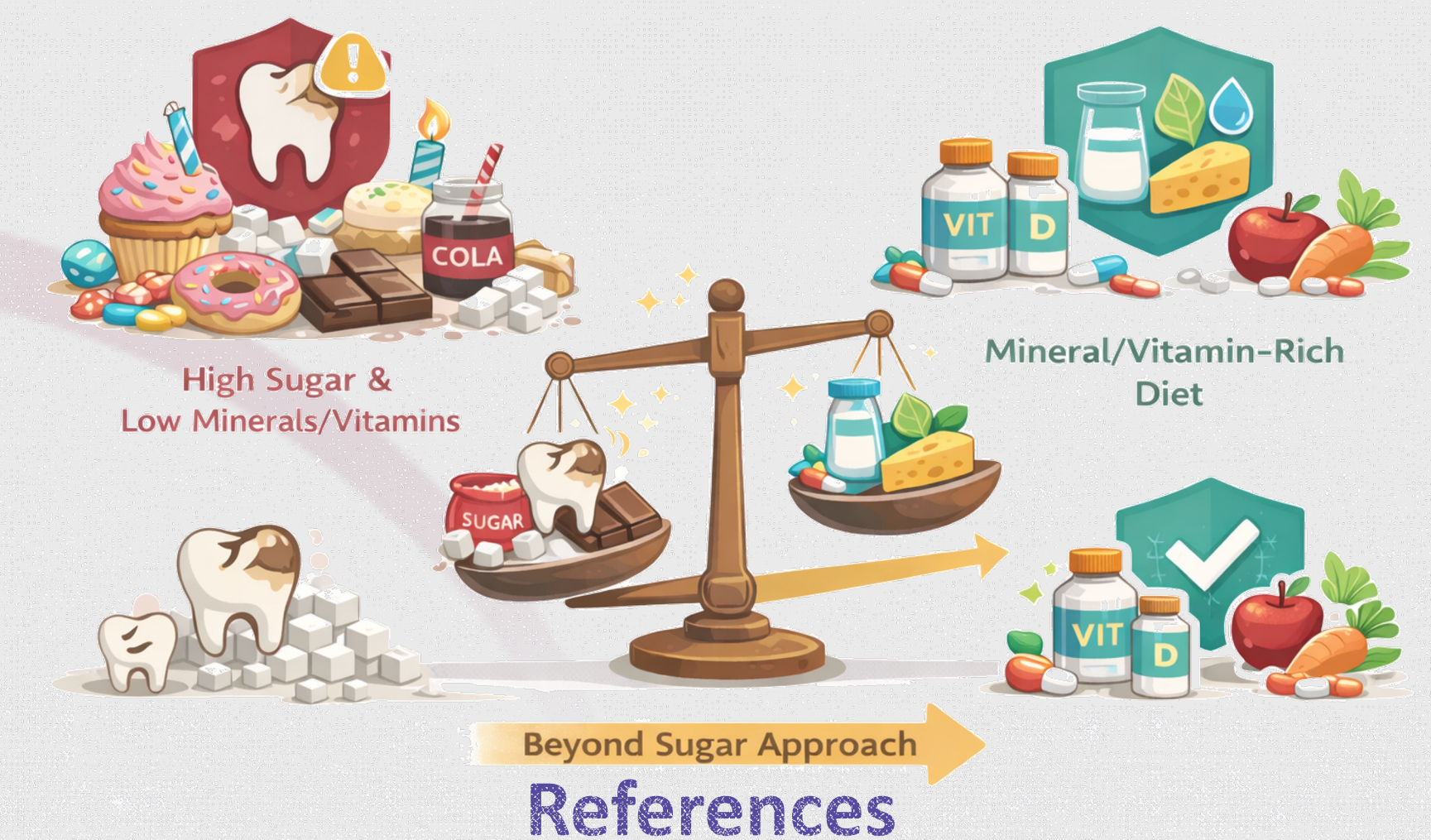
- Caries-affected children had higher sugar intake and lower calcium, phosphorus, and vitamin D intake compared to caries-free peers.
- PCA identified 3 major patterns: energy-dense, dairy/mineral-rich, and fruit/vegetable-rich. NMF revealed 4 distinct patterns including a high-sugar and a mineral-dense pattern.
- XGBoost achieved good predictive performance (AUC-ROC and AUC-PR) for classifying caries status.
- SHAP analysis: Sugar intake was the top risk factor; calcium, phosphorus, and vitamin D were the top protective factors.



- Dose–response curves showed a monotonic increase in caries risk with sugar and an inverse relationship with calcium, phosphorus, and vitamin D.

Conclusions

- High-sugar, low-mineral/vitamin dietary patterns are strongly linked to increased caries risk, while calcium, phosphorus, and vitamin D-rich patterns appear protective.
- Findings support a "beyond sugar" dietary counseling approach in pediatric dentistry — promoting protective nutrients alongside sugar reduction.
- Future longitudinal studies are needed to validate these cross-sectional findings and evaluate targeted dietary interventions.



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