A Predictive and Machine Learning Approach to Non-Invasive Anemia Diagnosis

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BACKGROUND
- Anemia, a condition characterized by impaired tissue oxygenation, weakness, fatigue, and decreased cognitive capacity, affects about 20% of the world’s population.
- Regions in Sub-Saharan Africa and South Asia are most affected by the disease, with the highest prevalence among children under five years of age and maternal populations.
- Patient hemoglobin (Hb) levels are the primary indicator of clinically diagnosed anemia.
- Currently, hemoglobin is measured using invasive techniques or automated hematology tools, which may be expensive and not readily available in low-resource settings.

PRIOR RESEARCH
- Numerous studies have demonstrated the potential of mobile learning to automate visual diagnosis of diseases and conditions in healthcare settings.1-2
- Mannino et al. proved that non-invasive diagnosis of anemia was possible using only a smartphone app and nail bed images, achieving an accuracy of 73.4 g/dL and a sensitivity of 97% (95% CI, 89–100%) when compared with CBC hemoglobin levels.3

QUESTION & HYPOTHESIS
Research Questions: Can predictive models and machine learning accurately estimate a patient’s hemoglobin concentration from images of their finger nail bed photos? How can a mobile app be designed to be user-friendly and accessible to patients and physicians?
Hypothesis: Predictive models and machine learning can be used to develop a non-invasive and accurate tool for anemia diagnosis using smartphone photos of the nail bed.

METHODS
- Data Collection:
  - Patients in this study were recruited from the Duke Sickle Cell Center and Duke Hematology Clinic.
  - Patient characteristics and images of the hand were obtained for each participant, along with a color calibrated meter alongside the hand.
- Data analysis was conducted in Python (Python 3.1.2)
- Datasets were used to train predictive models that leverage statistical analysis and machine learning to predict hemoglobin concentration from image data.
- A cross-platform mobile app is being developed as an accessible resource for testing in field settings.

RESULTS
- Color Spaces: A specific organization of colors or characteristics that describe color in image displays. Color spaces are commonly used in image processing. Various devices support different colors spaces.

<table>
<thead>
<tr>
<th>Color Spaces</th>
<th>HSV Hue, Saturation, Value</th>
<th>LAB Perceptual Lightness, Human Vision Colors (red, green, blue, yellow)</th>
<th>RGC (normalized RGB) Red, Green, Blue</th>
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| Models                | 1. Multinomial regression (MLR): statistical approach - originally published by Mannino et al.1 → performed with k-fold cross validation  
2. Random forest (RF): gradient boosted decision tree (machine learning) → trained and optimized through grid and random parameter searches |
| Table 1. Model Performance in Three Color Spaces (R² values) | | | |
|                        | HSV          | LAB          | RGC          |
| Multinomial Regression  | 0.59         | 0.69         | 0.64         |
| Random Forest          | 0.52         | 0.77         | 0.89         |

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CONCLUSIONS
- Results suggest that the random forest model within the RGC color space is the best predictor for hemoglobin concentration.
- The MLR model was more precise with its estimates and performed consistently across all color spaces.
- These results demonstrate the potential for predictive models, especially machine learning.
- Ultimately, these results will be used to improve point-of-care anemia diagnostics by developing a better hematology tool that is non-invasive, accurate, and affordable for low-resource settings.

FUTURE DIRECTIONS
- The project team aims to construct a similar dataset through international institutional collaboration to ensure a diverse patient population for the dataset.
- Future work will focus on implementing additional ML models such as a binary classification model or deep learning to improve predictive performance.
- The mobile app will be improved upon so that it may be deployed internationally on mobile devices.

ACKNOWLEDGEMENTS
- Thank you to Dr. Shah and Dr. El-Bitar in Duke University’s Medical Center for collaborating with us to collect patient data with which we trained our models.
- Thank you to Dr. Wax for serving as the faculty mentor for this BASS project and providing guidance.
- Thank you to Bass Connections Foundation for making this BASS course possible.
- Thank you to the advisors at the Global Alliance for Medical Innovation for the effort over the years to support this project and for being champions of student-driven medical innovation.

SUPPORT
- Duke University Medical Center
- Bass Connections
- Global Alliance for Medical Innovation

REFERENCES