VO2 Max mask

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1. Abstract

KTH Sports Technology wants a VO2 measurement tool, but current expensive products cannot adapt to changing needs. At a university, there is a desire to test new sensors, develop algorithms, or combine physiological measurements in new ways. Our solution provides VO_2 and CO_2 measurements with the possibility to add sensors and measurements as needed. The primary result will be an accessible, flexible, and affordable VO_2 measurement platform that opens up opportunities for both advanced research and practical use in sports and health at KTH.

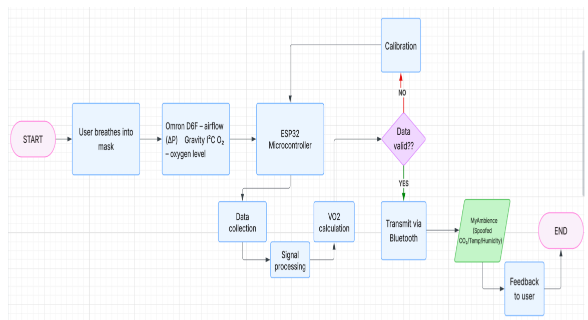
2. Introduction

VO_2 max (Mandsager K et al. 2018) is a key measure of cardiovascular health. Standard systems like metabolic carts are accurate but expensive, bulky, and limited to labs, restricting wider use. For a sport tech institute, where innovation and experimental sensor development are of high importance, the lack of adaptable and affordable VO_2 measurement tools represents a significant barrier to advancing both research and applied sport sciences.

Several alternative approaches have been proposed. Portable breath-by-breath analyzers and wearable metabolic measurement systems have emerged, aiming to increase accessibility in field environments. While such devices provide improved mobility, they are still relatively expensive and typically closed systems, limiting opportunities for researchers to modify or extend their functionality. Other studies that are based on the “Ekblom-bak" test (Ekblom-Bak et al., 2021) exist but often lack the accuracy of direct gas exchange. Existing devices, such as the VO_2 Master and laboratory carts, face important limitations: the VO_2 Master Pro lacks a CO_2 sensor, restricting full gas-exchange measurements (Montoye et al., 2020), while metabolic carts remain bulky, expensive, and confined to laboratories (McClung et al., 2023). As a result, current options do not fully meet the combined needs of affordability or adaptability for research and applied use.

In this work, we present a flexible and cost-efficient VO_2 measurement platform that produces reproducible results and allows integration of additional sensors, aiming to provide a useful solution for both research and applied use.

3. Design



A respirator mask channels exhaled air through two sensors: an SM9233 250PA Diff. Digital Pressure sensor (airflow, ΔP) and a Gravity I²C O_2 sensor (oxygen concentration). Sensor data is processed by an ESP32 TTGO T-Display, which performs data collection, signal processing, and VO_2 calculation. A calibration loop ensures valid data before transmission. Results are sent via Bluetooth to the Sensirion MyAmbience app, where values are spoof-mapped to CO_2, temperature, and humidity for visualization. The app provides graphical feedback. Component choices were motivated by availability and ease of integration: TE SM9233 for accurate airflow sensing, Gravity O_2 for simple I²C communication, and ESP32 for its built-in display and wireless connectivity.

GitHub link: https://github.com/Elin310/VO2max

4. Evaluation

Output from the Sensirion MyAmbience app showing VO2 data:

The graph above is taken from the MyAmbience computer app during our first tests. The data confirms that the system can capture dynamic changes in oxygen uptake during physical activity. Our mask was assembled with the exception of the battery and the on/off switch.

Method:

Participants: 4 healthy adults (20–39 years; mixed gender; recreationally active).
Protocol: Each subject completed two treadmill stages while wearing the prototype mask. The protocol was identical for all participants.
Data recorded: Breath-by-breath VO_2 (L/min), O_2 (L/min), and ventilation volume (L/min).
Analysis: Reproducibility was assessed through repeated trials on the same day.

Results:

Observations: Data curves were stable across repeated efforts, with no significant drift. Minor issues included condensation in the mask and slight sensor lag during peak ventilation.

Discussion:

The validation phase was delayed due to challenges with component delivery and initial software integration. We were able to test the prototype mask on four individuals and demonstrate that it provides reproducible measurements of VO_2, O_2, and minute ventilation across different individuals under controlled conditions. For the future, it would be beneficial to validate across a bigger test group and different types of activities. The inclusion of CO_2 analysis enables calculation of the respiratory exchange ratio (RER), offering additional insight into metabolic processes.

Limitations include the small sample size, single-day testing, and lack of calibration against an external reference device in this evaluation. Further work should assess inter-day reliability, environmental robustness (temperature, humidity), and long-term sensor stability.

5. Conclusion

The prototype measurement system produced consistent results. This supports its feasibility as a low-cost, field-deployable tool for tracking VO_2 and CO_2 dynamics in training environments. Future studies should expand participant numbers, include repeated testing across multiple days, and compare outcomes against laboratory gold standards to establish both reliability and validity.

References:

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Montoye et al., 2020 – *Validity and Reliability of the VO_2 Master Pro Portable Metabolic System*: https://pmc.ncbi.nlm.nih.gov/articles/PMC7523887/

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