Accuracy and Performance of Continuous Glucose Monitors in Athletes

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Continuous Glucose Monitors (CGMs)

The CGM consists of a pager-like monitoring device that receives information from a sensor inserted under the skin that detects glucose in the interstitial fluid.

- Originally designed to help Type 1 diabetics manage blood glucose levels
- Recently used in the Intensive Care Unit (ICU) and Neonatal Intensive Care Unit (NICU) to detect hypoglycaemia in at-risk babies
- CGM accuracy is dependent on Blood Glucose (BG) calibration measurements entered into the device every four times a day
- Much more frequent measure of blood glucose (5 minutely) but performance trade offs

(www.medtronic.com)
Optimisation of an athlete’s BG has the potential to

- Increase race performance – knowing when and what to eat during racing
- Speed recovery – Optimal replacement of glycogen stores
- Aid training - as blood glucose can reflect metabolic and inflammatory conditions

However, before these benefits can be realized the accuracy and performance of CGM devices in active athletes must be evaluated.
Recalibration of CGM data

**Blood Glucose = slope * (electric current - offset)**

**Linear Regression Calibration**

The CGM uses linear regression techniques combined with smoothing. This is a typical “built-in” method of calibration.

**Linear Interpolation Calibration**

A Re-calibration algorithm was used to make better use of the accurate blood glucose measurements.

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The diagram illustrates the recalibration process, showing the original CGM trace passing near the BG calibration measurements. After recalibration, the trace passes through the BG calibration measurements, improving the accuracy of the data.
Two fasting exercise tests were carried out 3 days apart:

At a later date, ‘fasting sedentary tests’ were carried out.
Mean absolute relative difference (MARD) and Offset was calculated between reference BG measurements collected during the fasting tests and the CGM trace:

\[
MARD = \text{mean}(\text{abs} \left( \frac{CGM - BG}{BG} \right)) \times 100
\]

\[
Offset = CGM - BG
\]

These metrics were assessed during:
- the exercise or sedentary phase only (0 – 120mins)
- Including the glucose bolus subsequent to these phases. (0 – 150mins)
Results

CGM Traces

Exercise tests

Sedentary tests
During Exercise MARD are equivalent if not better than the performance reported for CGM in diabetic subjects – 10.8 [8.7 – 16.7] % median [IQR] or 7.3 [5.4 – 10.9] % with recalibration.
**Results – Sedentary Performance**

Sedentary tests obtained worse performance attributed to two main factors:

- The reference measurements most likely biased during the sedentary test due to low apparent skin and leading to BG meters reading lower than expected values
- Interstitial fluid is not actively pumped like blood. It relies on muscle movement to circulate and mix.
There is a consistent positive bias evident, whether it be exercising or sedentary, or when applying the recalibration algorithm or the factory algorithm.
Limitations

The small data set is a major limitation of this study, however:

Based on the results of this study an Athlete trial plan was formed to further test the performance of CGM devices:

- 10 fit, healthy adults with a resting heart rate of 60 beats per minute (bpm) or lower
- Participants will have 2 Ipro2 CGM devices (Medtronic Minimed, Northridge, CA, USA) inserted in to their abdomen at least 24 hours before undertaking an exercise test
Protocol

- Very Similar protocol to the first exercise test

0.5g/kg Glucose

1g/kg Glucose

Ramp test until exhaustion (20W/5mins)

Submaximal zone (2.5W/kg)

BG every 10mins

BG every 5mins

BG every 10mins

Rest Day + Fasted overnight
Interim Results
## Interim Results

- 8/10 Subjects enrolled so far
- Very similar performance between recalibration algorithm and factory algorithm
- Very good performance across the board.
- Offset no longer evident

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<th>MARD</th>
<th>SG1</th>
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</table>
Conclusions

- Good Performance seen with CGM during exercise - Sensors agree well with each other and reference measurements.

- During sedentary periods the accuracy of the monitors was reduced - This decrease in accuracy is likely related to the fact interstitial fluid is not actively pumped like blood. It relies on muscle movement to circulate and mix.

- These result show real promise for using CGM to help optimize BG levels in an athletic active cohort.

- These differences in performance also provide insight into how these devices might be more optimally used in the target, more sedentary cohort.
Future work

- Develop Athlete Specific Metabolic Model:
  - Create Endogenous insulin secretion Model
  - Create Endogenous glucose production Model
  - Examine the sensitivity of SI to change in other glucose metabolism parameters

- Develop a protocol to optimise Athletes Blood Glucose using CGM values
  - Develop robust control methods to modelled variation and CGM dynamics
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