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The Accuracy of Continuous Glucose Monitors at High Attitude

Objective

Glucose monitoring is an essential part of diabetes management. Currently, the two available methods for personal glucose monitoring are self-monitoring blood sugar (SMBG) with blood glucose meters and continuous glucose monitoring system (CGM).

Although SMBG is an efficient method to monitor blood sugar, several trials [1, 2] showed that the accuracy of glucometers can be affected by environmental factors such as high altitude, humidity and cold weather, which raise the concern about their utility in such situations.

The two commonly used factory calibrated CGMs are Dexcom (Dexcom Inc.) and Freestyle Libre (Abbott). Although the Dexcom G6 System is permitted for use by the U.S. Food and Drug Administration (FDA) up to an altitude of 13,800 ft [3] and Freestyle Libre 14 and Freestyle Libre 2 CGMs are approved for use up to 10,000 ft altitude [4], the accuracy evaluation for these systems is usually done using hypobaric chamber to get a simulated altitude. We are not aware of any study done to assess the accuracy of CGMs at high altitude in a realistic environment.

Materials and methods

In this field study, 6 volunteers (4 male, 2 female) were able to perform and complete the study. Among the 6 candidates, 1 candidate had type 1 diabetes and the remaining were healthy. We placed 2 professional CGM (Dexcom G6 pro) on the arm and the abdomen of each participant. Each professional CGM was placed on the assigned participant at least 48 hours before the climbing.

We asked the participants to hike at different segments of Mount Evans in Colorado (14,265 ft) and blood glucose was collected at different altitudes starting at 12,860 ft immediately before the beginning of the hike and followed by samples at 14150 ft, 12152 ft, 11024 ft and 10036 ft respectively. All samples were centrifuged, and plasma separated and froze at –80°C to ensure the accuracy of the result before analysis after 72 hours. Plasma samples were compared retrospectively with CGM readings at each altitude by knowing the time of blood draw for each participant at each altitude.

Results

Results and mean absolute relative difference (MARD) values are summarized in Table 1. Overall, MARD values were notoriously elevated at each altitude knowing that the good reference value for MARD is < 10%. This was especially clear at 12860 ft where the MARD value was 40.8%. Overall, MARD values were comparable at the lowest altitude (10036 ft, MARD 18.5%) and the highest altitude (14150 ft, MARD 18.9%).

Also, there was interpersonal variation in MARD values between candidates ranging from as low as 11.9% to as high as 43.1%. Arm MARD was superior to abdominal MARD at each altitude with overall arm MARD of 21% and abdomen MARD of 26.6%.

Discussion

Although the MARD values were elevated in our study, such high values occurred previously in other

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Table 1. MARD % by Altitude/Temperature and Sensor Location

Altitude/temperature	Sensor location		
	Abdomen	Arm	Overall
10036 ft/ 75 F	19.1%	17.8%	18.5%
11024 ft/ 64 F	20.5%	16.0%	18.3%
12152 ft/ 64 F	25.3%	19.6%	22.5%
12860 ft/ 58 F	44.3%	37.3%	40.8%
14150 ft/ 62 F	23.6%	14.1 %	18.9%

MARD — mean absolute relative difference

studies [5] and it was mainly driven by very high MARD values for 2 of the candidates in our study.

MARD values were clearly elevated at 12860 ft and there were several factors that might lead to such high value. This was the first altitude where blood samples drawn after rapid shift in elevation by gaining >7000 feet in less than 1 hour and temperature was the lowest at this altitude. In addition to that, candidates ingest plenty of simple carbs at this altitude in preparation to the hike which might contribute to the difference between CGM values and plasma values.

There was no significant difference between MARD values at the lowest altitude and highest altitude which might be an indicative that CGM accuracy is not affected solely by the altitude value. Known factors that can affect CGM accuracy in our study include physical activity and the natural lag between interstitial and Plasma sugar readings. Other possible factors to consider include temperature and the speed of the change in the altitude rather than the actual altitude itself. These factors might explain the difference in findings between our study and other studies that evaluated the accuracy of Dexcom G6 [6].

Conclusions

Our small field study showed that CGM readings might be inaccurate at high altitude. Larger studies with more candidates/paired samples are needed to assess if patient who intend to do physical activity at high altitude can depend on CGM readings for glucose management and to look for the etiology of variation between CGM and plasma readings at high altitude if found. Several factors might play a role such as temperature, rapid change in altitude, physical activity and recent carbs ingestion. The main limiting factor to perform such large study in the future is the challenging difficult environmental factors and limited good candidates who can participate in such studies.

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Conflict of interest

None declared.

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