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The Accuracy of Continuous Glucose Monitoring and Flash Glucose Monitoring During Aerobic Exercise in Type 1 Diabetes

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Keywords
accuracy, continuous glucose monitoring, exercise, self-monitoring of blood glucose, sensors, type 1 diabetes

Continuous glucose monitoring (CGM) devices detect more hypo- and hyperglycemic events compared to self-monitoring of blood glucose (SMBG)[1] and are emerging as the standard of care for type 1 diabetes (T1D).[2] CGM devices are also shown to detect activity-related dysglycemia in youth with T1D.[3] However, the physiologic lag in equilibrium between CGM and SMBG of 5-15 minutes may cause a clinically important discrepancy during exercise.[4,5] It remains unclear whether CGM use during exercise suffices for glucose-management decisions. The data presented here examined the concurrent use of two real-time CGM (rtCGM), and one flash glucose monitor (FGM) compared with SMBG during aerobic exercise to determine how these devices could be used effectively to guide carbohydrate intake to avoid hypoglycemia.

A male subject with T1D (age 40 years; diabetes duration 25 years; HbA_{1c} 6.5%) was studied after informed consent was obtained. He wore a hybrid closed loop (HCL) insulin delivery system (Medtronic 670G, Minneapolis, MN; rtCGM1), Dexcom G5® CGM (San Diego, CA; rtCGM2) and Abbott FreeStyle Libre (Chicago, IL; FGM). The FGM and rtCGM devices were inserted 24-48 hours pre-exercise. SMBG was performed using a Contour® Next Link glucose meter (Ascensia Diabetes Care, Parsippany, NJ, USA) according to manufacturer recommendations. The HCL system was placed in "exercise-target" mode 1 hour before, disconnected during, and reconnected immediately after exercise. Pre-exercise meals were consumed >4 hours before activity. The exercise consisted of 1 hour of moderate-intensity running for 13 sessions over two months. Carbohydrate gels were consumed to avoid hypoglycemia during exercise based on the subject's experiences.

At exercise onset, glucose levels were higher with FGM (237 ± 45 mg/dL) versus rtCGM1 (198 ± 34 mg/dL), rtCGM2 (206 ± 35 mg/dL), and SMBG (215 ± 33 mg/dL) (all $P < .05$; Figure 1). SMBG values dropped rapidly during exercise from 215 ± 33 to 104 ± 23 mg/dL ($P = .0001$), despite significant carbohydrate intake (60 ± 24 g/session). SMBG measured lower than the other devices ($P < .0001$), while FGM showed a transient rise in glucose levels ($P < .05$). The mean absolute relative difference (MARD) was lower before exercise in rtCGM2 (6 ± 6%) versus rtCGM1 (9 ± 5%) and versus FGM (11 ± 8%) ($P = .02$). During exercise, the MARD increased across all devices (rtCGM1, 29 ± 24%; rtCGM2, 31 ± 21%) and was highest for FGM (44 ± 24%, $P < .001$).

This case study demonstrates that while rtCGM and FGM may correlate well with SMBG during periods of relative glucose stability, a clinically important lag effect is observed during aerobic exercise when glucose levels are rapidly declining. It is notable that SMBG levels dropped markedly during exercise despite using a HCL system set in "exercise-target" mode 1 hour pre-exercise, further highlighting the challenge that exercise places on developing HCL systems.[6] Overall, we found that the absolute difference in glucose levels between SMBG and rtCGM or FGM were greatest during the first 30 minutes of exercise, when SMBG had the largest decline. Interestingly, FGM overestimated glucose levels markedly throughout exercise and frequently reported a transient rise after exercise onset. Because of the observed overestimation in glucose levels during exercise, we recommend initiating carbohydrate feeding sooner (when glucose is <200 mg/dL and dropping) when relying on these devices, particularly with FGM.

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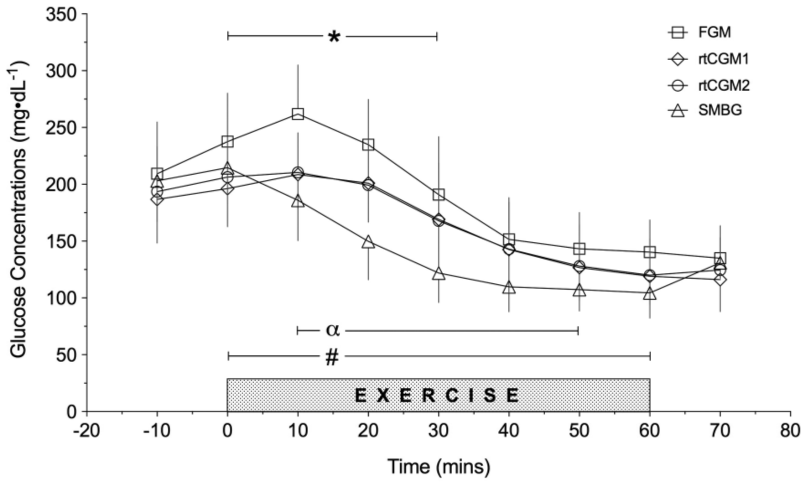

Figure 1. Absolute glucose concentrations for all devices (rtCGM1, rtCGM2, FGM, and SMBG) across 13 exercise sessions. * indicates that FGM is significantly higher than all other device (rtCGM1, rtCGM2, and SMBG) at $P < .05$. α indicates that SMBG values are significantly lower than both rtCGM1 and rtCGM2 at $P < .05$. # indicates that SMBG remained significantly lower than FGM values from the start to the end of exercise at $P < .05$. Data represents mean ± SD.

Abbreviations

CGM, continuous glucose monitoring; FGM, flash glucose monitor; HCL, hybrid closed loop; MARD, mean absolute relative difference; rtCGM, real-time CGM; SMBG, self-monitoring of blood glucose; T1D, type 1 diabetes.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: DPZ has received speaker's honoraria from Medtronic Diabetes and Ascensia Diabetes. MCR has received speaker's honoraria from Medtronic Diabetes, Insulet, Ascensia Diabetes, Novo Nordisk (via JDRF PEAK Program), Xeris Pharmaceuticals, Lilly Diabetes, and Lilly Innovation. JH has received speaker's honoraria from Dexcom and Novo Nordisk (via JDRF PEAK Program). No other potential conflicts of interest relevant to this article were reported.

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References

1. Danne T, Nimri R, Battelino T, et al. International consensus on use of continuous glucose monitoring. *Diabetes Care*. 2017;40:1631-1640.
2. American Diabetes Association. Standards of medical care in diabetes—2018. *Diabetes Care*. 2018;41(suppl 1):S1-S2.
3. Adolfsson P, Nilsson S, Lindblad B. Continuous glucose monitoring system during physical exercise in adolescents with type 1 diabetes. *Acta Paediatr*. 2011;100:1603-1609.
4. Basu A, Dube S, Veettil S, et al. Time lag of glucose from intravascular to interstitial compartment in type 1 diabetes. *J Diabetes Sci Technol*. 2015;9:63-68.
5. Siegmund T, Heinemann L, Kolassa R, Thomas A. Response to "discrepancies between blood glucose and interstitial glucose: technological artifacts or physiology: a reply." *J Diabetes Sci Technol*. 2018;12:900-902.
6. Riddell MC, Zaharieva DP, Yavelberg L, Cinar A, Jamnik VK. Exercise and the development of the artificial pancreas: one of the more difficult series of hurdles. *J Diabetes Sci Technol*. 2015;9:1217-1226.