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Case Report

Assessment of Blood Glucose Responses in a Female National-Level Marathon Runner Using Continuous Glucose Monitoring during a Real-World Marathon Race

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Abstract: Background: The effects of the use of continuous glucose monitoring (CGM) in elite endurance athletes are unclear. This case study reported the blood glucose (BG) levels of a female national-level marathon runner during a real-world marathon race. Methods: Heart rate and BG levels were monitored throughout the race. Results: The runner completed the race in 2:46 h:min, which was an improvement from her previous personal record by just under one min. Her BG levels were stable from approximately 5–40 km of the race at a mean concentration of 7.13 mmol/L, with a standard deviation of 0.20 mmol/L and a coefficient of variation of 2.8%. Increases in BG levels and heart rate were observed 6 min after the race and during the 40–42.195 km section, respectively. Conclusions: The runner broke her own record and exhibited stable BG levels throughout the race, with the highest BG value detected immediately after the race. Considering that quantity, content, and timing of pre-race meals and supplementation during the race can affect BG levels, future studies should assess additional detailed parameters in more detail and monitor multiple races with the same elite endurance athletes to acquire more definitive evidence on CGM usefulness among elite endurance athletes.

Keywords: carbohydrate; energy supply; distance running; heart rate; case report

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1. Introduction

Continuous glucose monitoring (CGM) has been attracting an increasing amount of interest among elite endurance athletes as a tool for evaluating the necessary carbohydrate intake during races and the effects of endurance training [1,2]. For instance, the NN Running Team and Eliud Kipchoge, who is the world's fastest marathon runner, have entered a contract with Abbott, a CGM manufacturer [3]. There is a growing body of research evidence regarding the use of CGM in non-athlete populations [2,4,5]. For example, a previous study reported that an educational module utilizing CGM was effective in improving exercise motivation [4]. Another study compared hunger training using CGM with fingerprick glucose monitoring in obese subjects and concluded that either method of measuring blood glucose (BG) was effective for learning to eat based on hunger [5]. However, because of limited studies focused on elite endurance athletes, the scientific value of using CGM to target this population remains unclear.

The history of research on BG levels during marathon races dates back approximate-ly 100 years. One of the pioneering studies in this field was conducted by Levine et al. [6], in which they examined the relationship between physical condition at the finish of the Boston Marathon and plasma glucose levels in 11 runners. They found intriguing patterns of plasma glucose levels with respect to the general post-race physical conditions of the runners. Specifically, the plasma glucose levels of the winner were within the typical range and his condition was good. In contrast, the physical condition of the runners who exhibited lower post-race plasma glucose levels was poor, characterized by symptoms such as asthenia and pallor. The following year, this group investigated the effects of implementing strategies for carbohydrate intake before and during the race in the runners

who completed the previous year's race and found that the plasma glucose levels were below the normal range [7]. As a result, the runners could prevent hypoglycemia and improve their general physical condition and race performance. Previously, 30 years ago, to understand the causes of running speed (RS) reduction during marathon races, research was conducted to identify the cause of late-race impaired running performance, specifically, the severe impairment known as "hitting the wall" [8]. Notably, they reported that 7 of 11 runners who "hit the wall" had reduced plasma glucose concentrations. These early studies made an important contribution to demonstrating the importance of preventing hypoglycemia during marathon races.

Previous studies using CGM in endurance sports have focused mainly on ultramarathon races [9–13]. To the best of the author's knowledge, scientific papers examining the monitoring of BG using CGM during marathon races are limited to a single case study of a recreational male runner [14]. That case study monitored BG five times during a marathon race in the same runner and reported that superior race performance was observed for a flat BG pattern, whereas the RS gradually decreased and the race performance worsened in the case of a pattern of descending BG. Based on these results, those authors concluded that CGM is a useful tool for monitoring glucose fluctuations during long-distance running.

Despite the great interest in, and enthusiastic marketing of CGM in the context of elite endurance sports, there is a paucity of scientific evidence about CGM's usefulness among elite endurance athletes. To address this gap, the present case study reports on the monitoring of BG during a marathon race in a female national-level marathon runner.

2. Materials and Methods

2.1. Participant

This case study employed a performance-analysis approach to investigate the performance of an experienced national-level female marathon runner. The runner had over 20 years of running training experience and had participated in more than 20 marathon races, with a personal record of 2:47 h:min. Prior to the target marathon race, the runner maintained a high level of training volume, i.e., 520 km/month. The study was ethically approved by the Human Ethics Research Board of the Public Health Research Foundation (No. 23A0002) and was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Measurements

The target race for this study was the Tokyo Marathon 2023, which was held on 5 March 2023. The performance indicators used for the analysis were RS, BG, heart rate (HR), and cardiac cost. The RS was obtained from the official website. BG was measured using the FreeStyle Libre sensor (Abbott Diabetes Care, Alameda, CA, USA) that was inserted into the subcutaneous tissue of the upper arm 2 days before the race. The amperometric sensor continuously measured glucose concentration in the interstitial fluid and stored glucose levels every 15 min for up to 8 h. The stored data were read using the FreeStyle Libre reader device (Abbott Diabetes Care, Alameda, CA, USA) and were downloaded on a PC using the FreeStyle Libre software (version 1.0). Because CGM measures glucose concentration in the interstitial fluid, there is a time lag of 5–10 min from actual BG levels [15,16]. The BG in mg/dL was converted to mmol/L by multiplying by 0.0555. HR was measured using an arm-worn HR monitor (Polar Verity Sense; Polar Electro, Kempele, Finland) with a sampling frequency of one reading. Cardiac cost was calculated by dividing HR by RS based on previous studies [17,18]. The RS and HR were averaged for every 5 km segment (for the 40–42.195 km, calculated for 2.195 km) [18,19].

3. Results

The runner's finishing time of 2:46 h:min represented an improvement of just under one min from her personal record. Table 1 presents the RS, HR, and cardiac cost (HR/RS) data recorded in each section of the race. The runner adopted a negative pacing strategy,

with the first half completed in 1:23 h:min and the second half completed in 1:22 h:min. The highest RS and HR values (peak HR: 171 bpm) were observed between 40 km and 42.195 km. The RS exhibited a low coefficient of variation (CV) of 1.0%, indicating a constant pace during the race.

Table 1. Running speed, heart rate, and cardiac cost during the marathon race. Running speed and heart rate are averaged values. Cardiac cost is calculated by dividing the heart rate by the running speed.

Segment	Running Speed (km/h)	Heart Rate (bpm)	Cardiac Cost (bpm/km/h)
0–5	15.2	152	10
5–10	15.2	153	10.1
10–15	15.1	154	10.2
15–20	15.1	152	10.1
20–25	15.2	156	10.2
25–30	15.2	156	10.3
30–35	15.4	160	10.4
35–40	15.2	162	10.6
Last	15.6	166	10.7

Figure 1 displays the BG levels before, during, and after the race. The BG levels were stable from ~5 to 40 km (0:23–2:38) of the race, at a mean of 7.13 mmol/L, standard deviation of 0.20 mmol/L, and CV of 2.8%. The highest BG levels were observed 6 min after the race, at 8.77 mmol/L.

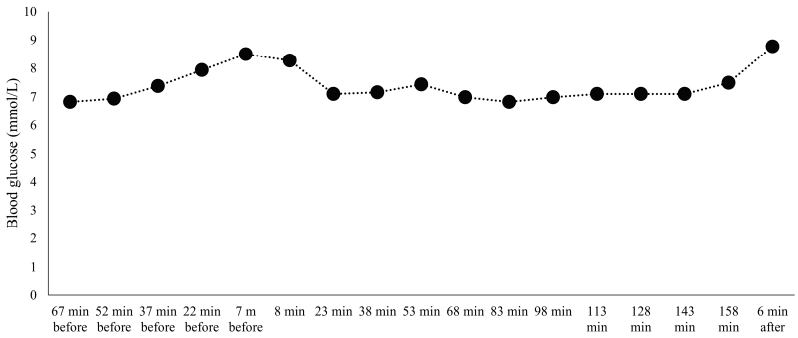

Figure 1. Changes in blood glucose levels before, during, and after the race. There is a time lag of 5–10 min from actual blood glucose levels.

4. Discussion

This case study provides novel data regarding the behavior of BG in a female elite (national level) runner during a real-world marathon race.

The BG was stable from ~5 to 40 km of the race. The results suggest that higher or sustained BG levels throughout the race indicate successful prevention of hypoglycemia [1]. In addition, the highest BG value was observed 6 min after the race ended. Considering that a delay of 5–10 min exists between the actual BG levels and the recorded CGM glucose levels [15,16], this may reflect a sympathetic activation that occurs during the end spurt of the race, resulting from glycogen breakdown in the liver [20]. In fact, the highest RS and HR values were observed for the 40–42.195 km part of the race (as shown in Table 1). Even though the runner did not ingest sufficient carbohydrates during the race (estimated to be less than 30 g of carbohydrate), it is likely that the runner had residual liver glycogen that was used during the final phase of the race; however, there are no scientific data to confirm this.

Our study detected higher BG levels before and after the start of the race. Because the present study did not quantify the carbohydrate intake before and during the race, a

detailed analysis could not be performed. Anecdotally, the runner ate Castella (Japanese sponge cake made of sugar, flour, and eggs) until about an hour before the race.

Because of the nature of the study design, a causal relationship between BG and race performance cannot be discussed. Nevertheless, the participant achieved a superior performance by breaking her personal record in the race, and the changes in RS and HR observed during the race were consistent with those of a superior race performance, as reported by previous studies [18,19,21]. Hence, it is reasonable to suggest that the BG pattern observed in this study was linked to the superior performance of this athlete.

The limitations of the present study were that evaluations were conducted only once during the race, the lack of a detailed evaluation of pre-race nutrition and training status, and not conducting a physiological test (i.e., maximal oxygen uptake and running economy test). The results of previous studies examining the relationship between BG pattern and endurance performance are inconsistent, and this is probably related to various factors including quantity, content, timing of pre-race meals, supplementation during the race [22–24], fitness levels [20], and race and/or ethnicity [25]. Thus, it will likely provide more valuable information to assess additional parameters in more detail and conduct measurements across multiple races with the same subjects.

5. Conclusions

In conclusion, the female elite runner who broke her own record in the marathon exhibited mostly stable BG levels during the race, with the highest BG value being detected immediately after the race. To determine the usefulness of CGM in elite endurance sports, further studies are recommended.

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Institutional Review Board Statement: The study was ethically approved by the Human Ethics Research Board of the Public Health Research Foundation (No. 23A0002) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from the subject involved in the study. Written informed consent has been obtained from the patient to publish this paper.

Data Availability Statement: The datasets presented in this article are not readily available because the present study used individual data. Requests to access the datasets should be directed to fuminori.takayama@ncis.org.

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Conflicts of Interest: The author declares no conflict of interest.

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