PREGLEDNI ZNANSTVENI RAD
REVIEWS

Hrvat. Športskomed. Vjesn. 2024; 39:14-17

CONTINUOUS GLUCOSE MONITORING (CGM): A TREND OR A NECESSITY IN SPORTS?

KONTINUIRANO PRAĆENJE GLUKOZE: TREND ILI NUŽNOST U SPORTU?

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DOI 10.69589/hsv.39.1.2

SUMMARY

Continuous glucose monitoring (CGM) is a sensor-based glucose-measuring technology, initially developed for diabetes management that gives insight into interstitial glucose levels. Healthy persons and athletes have increasingly used it, but in the mentioned instances it lacks data on how CGM-measured glucose values affect health outcomes and what are the limits of desired glucose levels. The main CGM use by healthy populations is to modify dietary choices according to personal metabolic responses although it should be used with caution, while its utility for understanding and modifying individualized dietary responses is limited by the numerous non-dietary factors influencing glycemic control. In the case of its use by athletes, one must additionally have in mind the duration and intensity of training together with its timing to meal.

Keywords: CGM, diabetes type 1, healthy population, athletes, energy demands, sport success

Ključne točke

- Continuous glucose monitoring (CGM) is an easily assessable metric to gain insight into athletes' dietary needs and could be used to monitor training load and perhaps answer the ongoing question of whether one is training too hard or not hard enough.
- More research is needed to determine the value of CGM in helping athletes with and without diabetes to optimize training and competition results and a healthy approach to training.

SAŽETAK

Kontinuirano praćenje glukoze (CGM) je senzorska tehnologija za mjerenje glukoze, prvobitno razvijena za bolju kontrolu šećerne bolesti tipa 1, kroz uvid u intersticijsku razinu glukoze. Danas ga sve više koriste zdrave osobe i sportaši, no u navedenim slučajevima nedostaju podaci o tome kako vrijednosti glukoze izmjerene CGM-om utječu na zdravstvene ishode i koje su granice unutar kojih bi trebale biti željene razine glukoze. Glavna uporaba CGM-a od strane zdravih osoba je modificiranje prehrambenih izbora u skladu s osobnim metaboličkim odgovorima, iako se tada treba koristiti s oprezom, jer je njegova korisnost za razumijevanje i modificiranje individualiziranih prehrambenih odgovora ograničena brojnim nedijetetskim čimbenicima koji utječu na kontrolu razine šećera u krvi. U slučaju da ga koriste sportaši, osim navedenog, treba voditi računa o trajanju i intenzitetu treninga, kao i o vremenu koje je proteklo između treninga i obroka.

Ključne riječi: CGM, šećerna bolest tipa 1, zdrava populacija, sportaši, energetski zahtjevi, sportski uspjeh

Key Points

- Kontinuirano praćenje glukoze (CGM) daje uvid u prehrambene potrebe sportaša i omogućuje praćenje trenažnog opterećenja te bi mogao dati odgovor na učestao pitanje trenira li sportaš previše ili nedovoljno.
- Potrebno je više istraživanja kako bi se utvrdilo u kojoj mjeri CGM koristi sportašima sa i bez šećerne bolesti u optimiziranju rezultata treninga i natjecanja te zdravom pristupu treningu.

INTRODUCTION

Continuous glucose monitoring (CGM) is a sensor-based glucose-measuring technology, initially developed for diabetes management. Unlike traditional blood glucose (BG) enabled by repetitious finger pricking, CGM measures glucose in the interstitial fluids and delivers data after manual sensor scanning or wireless transmission to a receiver. Obtained glucose results are assumed to be equivalent to BG concentrations, but show a variable (usually 5-10 minutes) lag time. Moreover, displayed readings are accompanied by arrows indicating future glucose trends, i.e. stable glucose, glucose rise, or glucose fall.[2] To use the CGM data properly, one must understand its working pattern. After a carbohydrate intake, glucose is absorbed into the blood, and only after 15 to 20 minutes into the interstitial fluid, where it becomes available for the CGM sensor. Therefore, in cases of rapid glucose change (such as during exercise), CGM can seem less accurate due to the lag time (although it accurately reflects what is occurring in the bloodstream, only with a delay).[18, 23]

Currently, CGM is increasingly used by healthy persons but still lacks data on how CGM-measured glucose values affect their health outcomes and where the limits of desired glucose levels should be set.[12] The best estimations are drawn from glycosylated hemoglobin A1c (HbA1c) of 5.7% (which is a characteristic of long-term normoglycemia), and suggest an upper limit for sensor-measured glucose for healthy people should not exceed 7.8 mmol/L for a longer period (i.e. without a tendency to normalize).[17] In practice, the main CGM use by healthy populations is to modify dietary choices according to personal metabolic responses. This can though, lead to oversimplification of postprandial (after the meal) glucose levels, which are not entirely related to meal composition but are also affected by the timing of the meal to the previous meal and its composition, stress, sleep, and in females by menstrual cycle phase while the timing of physical activity and its duration and intensity additionally challenge glucose homeostasis and insulin sensitivity.[8] Therefore, although CGM offers insights into glucose dynamics, its utility for understanding and modifying individualized dietary responses is limited by the numerous non-dietary factors influencing glycemic control.[16]

CGM USE IN T1DM DURING EXERCISE

In diabetic patients, under resting conditions, CGM use enables better glucose management, with fewer excursions to hyper- or hypoglycemia, the possibility to spend more time in the glucose range (TIR), achievement of desired glycosylated hemoglobin A1c (HbA1c), and fewer chronic complications of diabetes.[11]

Glycemic management around exercise is on the other hand challenging for people with type 1 diabetes (T1DM) and can compromise good glycemic control.[23] Traditionally used self-monitoring of BG levels can be inconvenient for athletes with T1DM during training or competition, as it asks for interruption of exercise and is time-consuming. Therefore, new technology in terms of CGM is gaining popularity, and its accuracy and safety are currently tested under different energy-related exercise activities.[23] CGM use by athletes with T1DM ensures highly individual insights into glucose and provides an opportunity for personalized care. It can therefore aid more precise decisions on carbohydrate intake and/or insulin dose modifications, which is especially important for avoiding hypoglycemia, defined as a a sensor reading <3.9 mmol/L for 15 consecutive minutes. Data from laboratory studies have shown that hypoglycemia is usually preceded by 15 minutes to half an hour of slow drop in BG, during which an individual can feel „warning symptoms“ of dizziness, lack of energy, sweating, and tiredness. The mentioned symptoms can easily be neglected during training or competition, might occur more rapidly, and end in severe hypoglycemia, or impair the sports result. Therefore, monitoring glucose and glucose trends by CGM, particularly during prolonged endurance sports, can help an athlete with T1DM avoid severe hypoglycemia by carbohydrate intake at a glucose level of around 4.5 mmol/L accompanied by a downward trend arrow.[2]

CGM USE IN HEALTHY ATHLETES

Understanding the glucose delivery to and uptake by the working muscles is one of the most important issues in sports physiology affecting athletes' exercise capacity and sports results. In the average-sized adult, only a small amount of glucose, about 4 grams is readily available in the bloodstream, playing a critical role in exercise performance[22], and it has to be maintained in a tight range, avoiding excursion to either hypoglycemia or hyperglycemia for (best) performance. Interestingly, until recently, little research has focused on BG level as a parameter to optimize training in healthy athletes. Mentioned is probably due to the needed unpractical laboratory glucose measurements; therefore, a large amount of data concerning hours past exercise was unavailable.[9]

In the last few years, the use of CGM by healthy people and athletes from endurance sports has gained a lot of attention. Indeed, the importance of monitoring interstitial glucose levels finds its grounds in studies corroborating the role of interstitial glucose sensing rather than blood sensing by the brain and muscles.[4] Moreover, the importance of monitoring glucose during sports emerged with the understanding that healthy people spend 80-85% of the time in the target glucose range (TIR) during exercise, while the remaining time they are either below (TBR) or above the target (TAR)[7], which can be influenced by factors such as sex, body mass index, and age along with exercise intensity, duration, and type[6], Figure 1. It is therefore crucial to understand glucose homeostasis during exercise[10;21],but

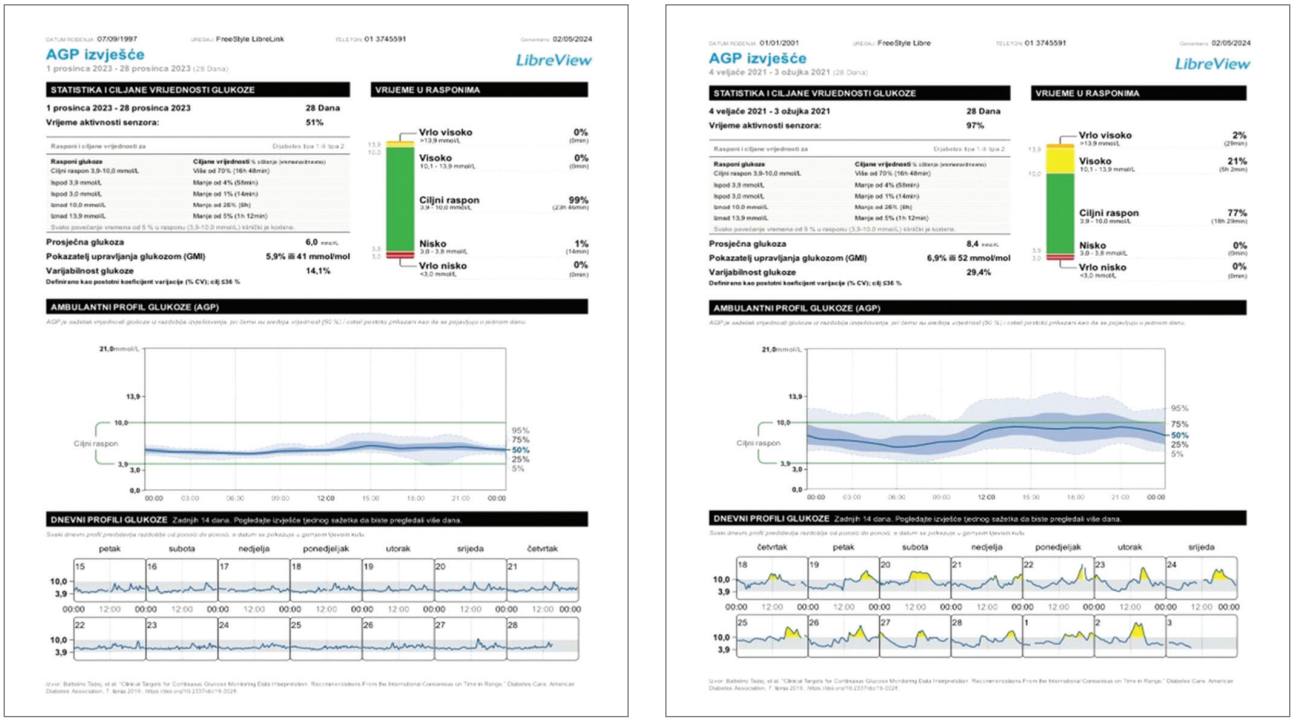

Figure 1. CGM reports from healthy athletes competing in endurance sports
Slika 1. CGM izvještaj zdravih sportaša koji se natječu u sportovima izdržljivosti

also bear in mind that different sensors as well as the site of placement and the timing of their placement (at the beginning and just before their expiration) can affect the accuracy of measurements.[21] Therefore, CGM data are still difficult to interpret within the context of sports performance and therefore must be used with caution.

GLUCOSE AS A FUEL

The simple sugar glucose is the preferred energy source for most human cells, including muscle cells. The ratio between glucose and fat as fuel varies depending on the energy demands at a given moment. During high-intensity workouts, usually defined as intensities above an individual's anaerobic threshold, enzymatic reactions break down glucose into pyruvate, which is then transformed into lactic acid (or lactate, as it is often called in sports science). This anaerobic process provides the cells with a net gain of 2 ATP molecules and does not require oxygen. Conversely, if the intensity is lower than the anaerobic threshold, pyruvate is converted into Acetyl-CoA and metabolized in the mitochondria via the Krebs cycle. This aerobic process provides the cells with 32 to 38 net ATP molecules without accumulating lactate and requires oxygen.[1,19]

Sports and activities are often divided into categories based on the fuel sources and energy demands needed during the event. The intensity and duration of the activity dictate whether the body primarily uses glucose, glycogen (stored glucose), or fat for energy.[14] The two main groups are aerobic and anaerobic sports. Anaerobic activities of high intensity and duration between 30 and 120 seconds largely depend on glucose as the primary and almost sole energy source to provide instant energy for short bursts. On the other hand, while glucose is also crucial in long-duration aerobic sports, the amount of glycogen stored in muscles and the liver significantly influences the onset and level of fatigue, despite the availability of fat as an alternative fuel. This is due to the body's evolutionary "fight or flight" response, where glucagon triggers a rise in available glucose to preserve life. Thus, when glycogen stores diminish, even in endurance events like marathons that can be completed using fat stores, the body signals fatigue to conserve what remains of the glycogen for emergencies. It seems that at low but nonzero glycogen concentrations, there is insufficient glycogen to supply fast energy needs and fatigue occurs.[20] The use of CGM, giving insight into athletes' fueling, therefore seems to be a technology we would rely much more on. Indeed, it has been shown that measuring glucose can be used as a marker of reduced energy availability in the context of relative energy deficiency in sports (REDs)[5], and fasting hypoglycemia, which was considered as a marker of overtraining, can also indicate low energy availability, while nocturnal hypoglycemia can disrupt sleeping and negatively affect recovery.[15]

CONCLUSIONS

Continuous glucose monitoring (CGM) can aid athletes with type 1 in decision-making around sports to reduce hypo and hyperglycemia and influence better sports

achievements. Moreover, gaining an insight into highly variable glucose profiles in healthy athletes suggests that interstitial and blood glucose levels may be an overlooked marker in optimizing training, athletic results, and recovery. Therefore, CGM is a promising technology for monitoring energy balance, glucose availability, performance, and recovery status in athletes with and without diabetes.

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