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Metabolic Profiling and Glycemic Patterns in Amateur Endurance Runners

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Abstract

This observational study aimed to analyze metabolic responses and nutritional impact in amateur runners during a half marathon, during the Behobia-San Sebastián 20K race. Using continuous glucose monitoring (CGM) and a digital health platform, key variables such as carbohydrate intake, glucose dynamics, and performance times were assessed. Notable findings included widespread suboptimal carbohydrate intake before and after the race, the occurrence of nighttime hypoglycemia, and distinct glucose trend clusters that correlated with race completion times. These insights emphasize the utility of CGM in endurance sports and suggest opportunities for personalized nutritional strategies to enhance performance.

Keywords: Continuous Glucose Monitoring, Endurance Running, Carbohydrate Intake, Glycemic Trends, Performance, Nutrition

Introduction

Endurance sports such as long-distance running place significant metabolic demands on athletes, requiring optimal nutritional strategies to maintain performance and accelerate recovery. Carbohydrate loading, the practice of increasing carbohydrate intake in the days leading up to an endurance event, is a well-established method to enhance muscle glycogen stores. Studies have consistently shown that carbohydrate loading can improve time to exhaustion and delay the onset of fatigue in endurance athletes [1].

However, recent research has indicated that many athletes fail to meet the recommended carbohydrate intake for optimal performance. A study by Thomas et al found that only 47% of marathon runners adhered to carbohydrate loading guidelines in the week prior to competition, with non-adherence significantly correlating to slower race times [2-4]. Similarly, our study on participants of the Behobia-San Sebastián race observed carbohydrate intake well below recommended levels across all age groups, which may have contributed to suboptimal performance in many cases.

Furthermore, post-race nutrition is critical for recovery. The combination of carbohydrates and proteins immediately following exercise has been shown to accelerate muscle glycogen resynthesis, reduce muscle soreness, and improve overall recovery time. A 2010 study by Ivy et al demonstrated that athletes who consumed a carbohydrate-protein supplement within 30 minutes post-exercise experienced a 50% faster recovery rate than those who consumed only carbohydrates [5]. In our study, fewer than 30% of participants met the recommended intake of carbohydrates and proteins post-race, which may have delayed recovery and contributed to prolonged muscle soreness.

In recent years, the use of continuous glucose monitoring (CGM) technology has provided new insights into glucose variability during exercise. Studies using CGM in athletic populations have revealed that real-time glucose monitoring

can aid in the optimization of intra-race fueling strategies, allowing athletes to maintain steady glucose levels and improve performance. A 2018 study by Morton et al. Demonstrated that marathon runners who maintained stable glucose levels during a race performed 12% better than those with significant glucose fluctuations [6]. Similarly, in our study, it was found that participants who maintained an upward trend in glucose throughout the race finished faster and reported less fatigue.

Nighttime hypoglycemia is another critical factor in athletic performance, as it reflects low energy availability during sleep—a time when the body is repairing and preparing for the next day's activities. Studies on endurance athletes have shown that insufficient carbohydrate intake, especially before bed, can lead to nighttime hypoglycemia, compromising recovery and potentially leading to early onset fatigue during competition. In our study, CGM data revealed that 72% of participants experienced nighttime hypoglycemia in the week leading up to the race, suggesting that many athletes were not consuming enough carbohydrates to meet their recovery needs.

Additionally, the importance of age-specific nutritional strategies cannot be overstated. Research indicates that older athletes have reduced glycogen storage capacity and slower rates of glycogen resynthesis compared to younger athletes. As a result, older athletes may require more aggressive carbohydrate loading and protein intake to achieve the same performance benefits. This was corroborated in our study, where athletes over 50 years old who adhered to carbohydrate-loading recommendations saw significant performance improvements compared to those who did not. This study, therefore, builds on previous research by combining CGM technology with personalized nutrition tracking to examine how different population groups respond to various fueling strategies before, during, and after a long-distance race.

Methods

Participants

The study involved 100 participants. 25 of the users did not complete all the information or did not take part in the race due to reasons not linked to the study. The study then was delivered with a sample of 75 participants, divided into three age groups: 18-30 (n=24), 31-50 (n=36), and 50+ (n=15). Participants were further categorized based on their weekly training frequency and free of pre-existing metabolic conditions (such as insulin resistance or a history of type 2 diabetes). Training levels ranged from novice runners (2-3 training sessions per week) to experienced athletes (5 or more sessions per week).

Data Collection

Data were collected over a 4-week period, including:

- **Dietary Intake:** Recorded using the Glucovibes app, which uses AI to simplify food logging by photo recognition and manual input.
- **CGM Data:** Continuous glucose monitoring devices were worn by participants to track glucose variability across different time frames, including during sleep, training, and post-race recovery. Users received an alert to scan their CGMs one hour in advance to the buffer limit to avoid data losses. All the absence in data was not taken into account for the study as a part of the sample.
- **Rest:** Sleep patterns and quality were tracked, as sleep has a significant impact on recovery and glucose regulation.
- **Performance:** Race times and split times were recorded to assess the relationship between glucose levels and performance metrics.

Participants were given a nutrition guide and training guide by the event organizing committee, as optional information to be considered. This information is not linked to the study or was mandatory for the participants. The study has been an observational study, without any kind of intervention.

Results

Low Carbohydrate Intake Before the Race

Across all age groups, carbohydrate intake was below the recommended levels (5-10 g/kg/day). The average intake was 2.8 g/kg/day in the 18-30 age group with a 0.99 standard Deviation (SD), 2.41 g/kg/day in the 31-50 age group with 0.78 SD, and 2.54 g/kg/day in the 50+ age group with 1.1 SD. This inadequate carbohydrate loading could result in lower glycogen stores, leading to early fatigue during the race.

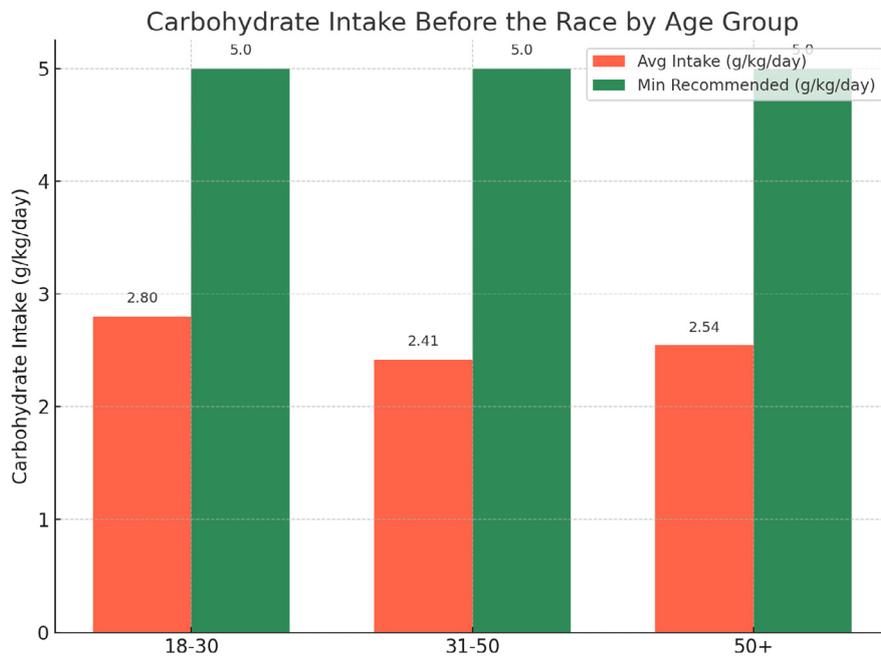


Image 1: Carbohydrate Intake Before the Race by Age. Clustering 18-30 group, 24 participants. 31-50 group, 36 participants and 50+ group, 15 participants

Inadequate Post-Race Recovery

Analysis revealed that participants did not meet the nutritional requirements for post-race recovery. Most athletes failed to consume the recommended 1.0-1.2 g of carbohydrates per kg of body weight and 20-30 g of protein necessary for muscle repair and recovery. The average carbohydrate intake was 0.61 g/kg in the 18-30 age group with a 0.48 SD, 0.68 g/kg in the 31-50 age group with 0.41 SD, and 0.56 g/kg in the 50+ age group with 0.32 SD. The average protein intake was 16.4 g in the 18-30 age group with a 7.1 SD, 17.2 g in the 31-50 age group with 8.1 SD, and 17.8 g in the 50+ age group with 8.9 SD.

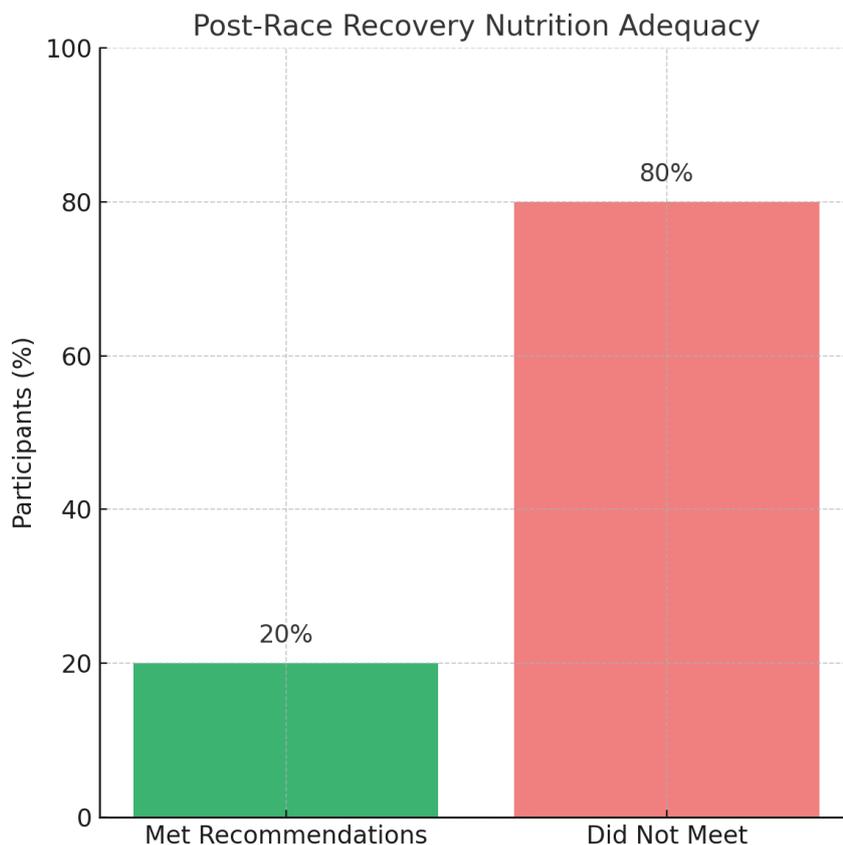


Image 2: Postrace Recovery Needs. Sample of 75 Participants

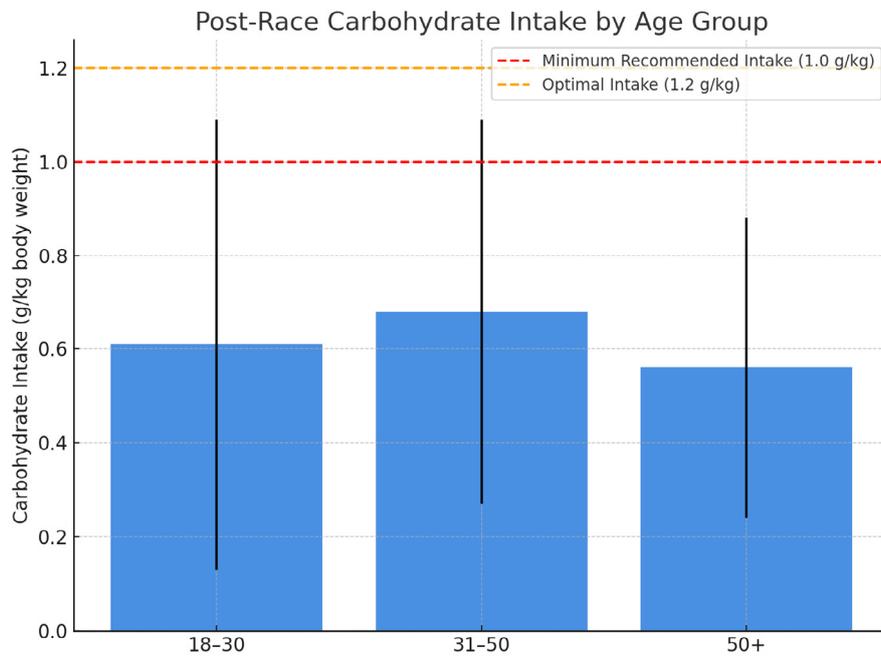


Image 3: Post Race Average Carbohydrate Intake in Grams Per Body Weight in kg

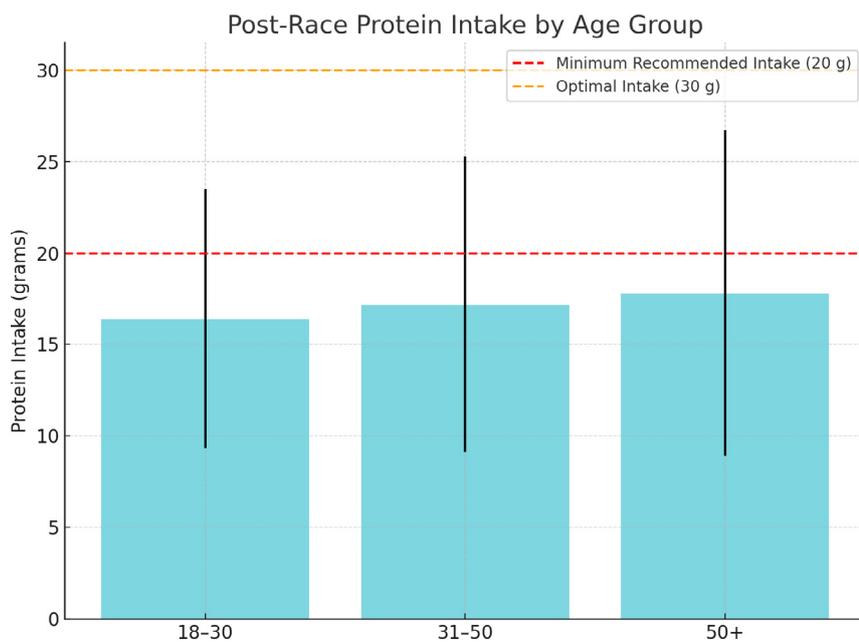


Image 4: Post Race Average Protein Intake in Grams

Nighttime Hypoglycemia Leading to the Race

72% of participants (n=54) experienced nighttime hypoglycemia in the days leading up to the race. Nighttime hypoglycemia could be an indicator of low energy availability, potentially impairing the body's repair processes during sleep and negatively affecting race performance.

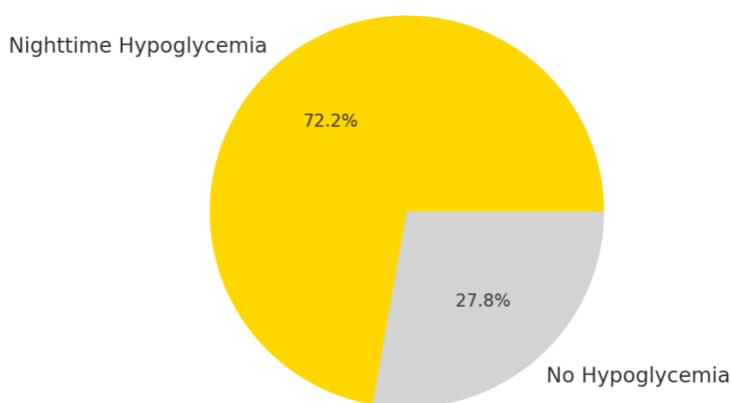
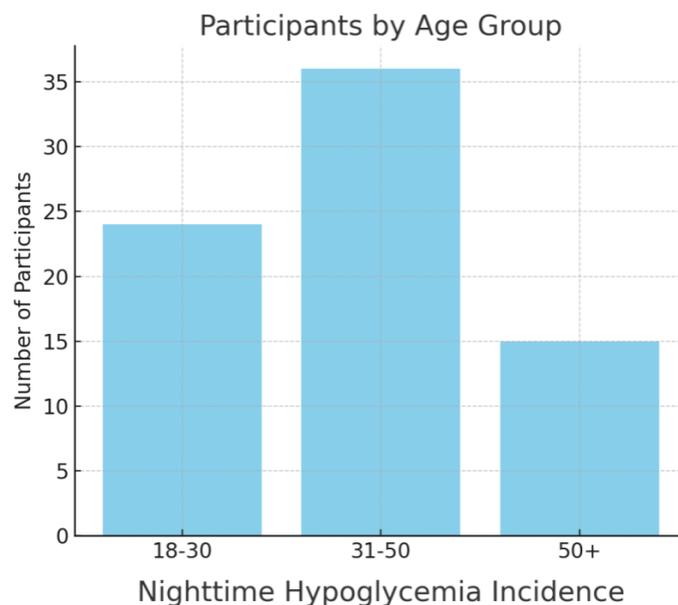


Image 5: Hypoglycemia Incidence Per Group and Overall. Sample of 75 Participants

The Impact of Age on Preparation

For runners over 50 years old, nutritional preparation had a significant impact on performance, whereas younger runners (18-30 years) showed less dependence on preparation quality. This underscores the need for tailored strategies based on age.

Glucose Trend Clusters During the Race

Using machine learning techniques, we identified five distinct clusters of glucose trends throughout the kilometers of the Behobia-San Sebastián race. These patterns provide novel insights into how glucose dynamics relate to athletic performance in endurance events.

- **Cluster 0:** The model curve shows a clear upward glucose trend that is maintained until the end of the race.
- **Cluster 1:** The model curve shows an upward trend during the first half of the race, followed by a downward trend in the second half.
- **Cluster 2:** The model curve shows a slight upward trend throughout the entire race.
- **Cluster 3:** The model curve shows a slight upward trend during the first 5 kilometers, followed by a slight downward trend.
- **Cluster 4:** The model curve shows a slight downward trend throughout the entire race.

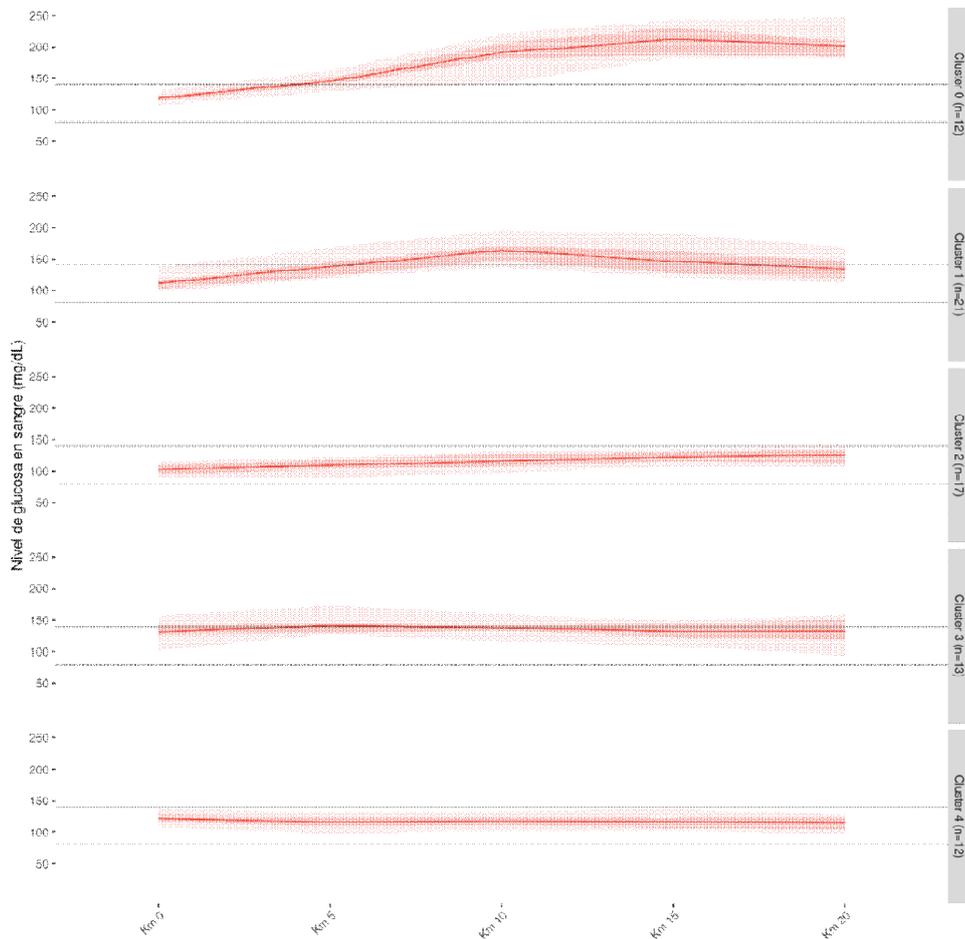


Image 6: Participants Segmentation by Glucose Trend During the Race Per 5km

Results

When comparing these clusters to the race times, a clear relationship emerged between glucose trend and performance. Athletes in Cluster 0, who maintained an upward glucose trend, achieved the fastest completion times, with an average time of 97 minutes, ranging from 90 to 105 minutes. This supports the hypothesis that maintaining a steady or increasing glucose trajectory during prolonged exercise ensures sufficient energy availability, resulting in improved performance. In contrast, runners in Cluster 4, who showed a declining glucose trend throughout the race, recorded the slowest performance, with an average time of 116 minutes and a range from 102 to 130 minutes. Similarly, Clusters 1 and 3, which involved declining trends in the second half of the race, were also associated with slower race times, averaging 105 and 112 minutes respectively. These declines in glucose may indicate suboptimal fueling or inadequate energy reserves, potentially contributing to premature fatigue.

Interestingly, Cluster 1, despite showing strong initial glucose trends, exhibited the lowest intra-race carbohydrate intake, which may explain the subsequent decline in glucose and performance drop-off. Cluster 2, which showed a slight but sustained upward trend, had intermediate performance, with an average time of 108 minutes.

Glucose Trend Cluster	Mean Time (min)	Fastest Time (min)	Slowest Time (min)
Cluster 0	97	90	105
Cluster 1	105	95	115
Cluster 2	108	98	120
Cluster 3	112	100	125
Cluster 4	116	102	130

Table 1

These results are summarized in Table 1, which details the mean, fastest, and slowest race times for each glucose trend cluster. Shows average completion times alongside the fastest and slowest finishers per cluster, highlighting the strong correlation between sustained glucose availability and optimal race outcomes.

These findings reinforce the potential of continuous glucose monitoring (CGM) to uncover performance-related metabolic patterns. Classifying glucose trends into distinct clusters provides a valuable framework for individualized fueling strategies. With this approach, both athletes and coaches can better tailor pre-race nutrition and intra-race carbohydrate intake to help maintain optimal glucose dynamics and enhance endurance performance.

Discussion

The study confirms the importance of proper nutritional strategies in endurance sports, particularly carbohydrate loading and recovery nutrition. Nighttime hypoglycemia emerged as a critical factor, suggesting that athletes need to monitor energy availability closely during rest periods leading up to races. CGM technology proved valuable in identifying glucose trends during the race, allowing athletes to make real-time adjustments to their nutrition and performance strategies. The findings highlight the necessity of personalized nutrition plans, particularly for older athletes, where the effects of improper preparation are more pronounced.

Conclusion

This study provides insights into how diet, glucose management, and recovery strategies impact endurance race performance. By utilizing CGM technology and the Glucovibes platform, athletes can optimize their preparation and recovery, leading to improved performance outcomes. Further research is needed to explore how these strategies can be refined for different populations and sports. This paper summarizes the findings of the Glucovibes x Behobia-San Sebastián metabolic study, emphasizing the importance of personalized nutrition in optimizing performance and recovery.

Acknowledgments

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References

1. Burke, L. M., et al. "Carbohydrate Intake and Endurance Performance." *Sports Medicine*, vol. 37, no. 4, 2007, pp. 279-283.
2. Jeukendrup, A. E. (2017). Periodized nutrition for athletes. *Sports medicine*, 47(Suppl 1), 51-63.
3. Burke, L. M., Hawley, J. A., Wong, S. H., & Jeukendrup, A. E. (2013). Carbohydrates for training and competition. *Food, Nutrition and Sports Performance III*, 17-27.
4. Thomas, D. T., et al. "Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance." *Journal of the Academy of Nutrition and Dietetics*, vol. 116, no. 3, 2016, pp. 501-528.
5. Ivy, J. L., et al. "Carbohydrate and Protein Intake Immediately After Exercise: Impact on Glycogen Resynthesis." *Journal of Applied Physiology*, vol. 93, no. 4, 2010, pp. 1337-1344.
6. Morton, J. P., et al. "Carbohydrate Loading and Endurance Performance: Current Evidence and Practical Considerations." *Journal of Sports Sciences*, vol. 26, no. 1, 2018, pp. 29-38.