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The Basics of Carbohydrate Periodization for Athletes and Coaches

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ABSTRACT

Prupose of Review: This review provides a brief and summarized form, the main and most used carbohydrate periodization strategies that can improve the performance of endurance athletes.

Recent Findings: Currently, various carbohydrate cycling approach they bring improvements on performance for endurance athletes. With regard a better store muscle glycogen and improvement in their performance. Although, guidelines of these strategies are still something deserve to be elucidated. It is especially important to provide real fundamentals to direct professional acting involved in this conduct in a summarized way and elucidate doubts and questions about the most used carbohydrate periodization strategies in the literature. As well as a carbohydrates-specific amount for a exercises-specific performed amount.

Summary: Same know as is complicated to assume a single strategy for one sport or even a single strategy for all athlete type, the strategies will have arguments for and against, it is up to the coaches together with their athletes to define which strategy is best applied for that season, and the strategies presented in this review demonstrate an improvement in the performance of endurance athletes.

Introduction

The carbohydrate (CHO) periodization has been a potential strategy for which to amalgamate train-low paradigms and used for improving form store muscle glycogen and induce additional benefits on endurance athletes performance [1] as well as for elite football athletes [2] based on fueling for the athletes work required. These practices of initiating exercise with low muscle glycogen content has grown in popularity over recent years [3] and can show to professionals as a new way of prescribing diets for high performance athletes. Although, the used strategies lowering muscle glycogen through prolonged aerobic exercise with high fat low carb diet increases the metabolic importance on fat as a fuel source, while sparing carbohydrate during exercise [4]. there are still gaps need to be filled about how to apply a particular strategy to a athlete specific-type. When muscle glycogen content is low, fat oxidation is optimized, and nutritional guidance is to consume carbohydrate during prolonged exercise to sustain submaximal performance [5]. But, when low carb diet used for a prolonged period, around 15 days, the damage in the oxidation of carbohydrates is clear, even worsening insulin sensitivity of the athletes [6]. Therefore, aiming these unknowns regarding dietary prescription models of carbohydrate periodization strategies, athletes in general need a specific carbohydrate periodization strategy aligned with their personal and exercise profile, brought in this review to better target professionals when applying the strategies in practice.

The Mechanisms Behind Carbohydrate Periodization

The glycogen are particles distributed within the muscle cell to support the energy needs during exercise and are found roughly 75% located adjacent to the sarcoplasmic reticulum and mitochondria, 5 to 15% in contractile filaments as subsarcolemmal glycogen and other 5 to 15% are found between the sarcolemma and the contractile filaments [7]. The exercise makes the GLUT4 transporters move into the sarcolemma without the insulin assistance to aiding in glucose uptake. Simultaneously, glycogen degradation increases from exercise come in response to changes in the concentration of metabolites into the cell. Both molecules, those released from the blood and those released from glycogen itself are oxidized to produce the adenosine triphosphate (ATP) molecules required to sustain muscle contraction [7].

The exercise triggers mammalian target of rapamycin (mTOR) signaling [8]. Already exercising in reduced conditions CHO availability increases the lipolysis in adipose and intramuscular tissue by increased circulating adrenaline concentrations, wich generate fat free acids (FFA), which they will later interfere in the mTOR pathway creating adaptations that can optimize store future glycogen [9]. In addition, the consuming pre-exercise meals rich in CHO and / or CHO during exercise can downregulate lipolysis and reduce both AMPK and p38MAPK activity, thus having negative implications for downstream regulators [9]. In a way, the adaptations need to be well elaborated so that it can, in fact, induce new metabolic changes in the cell about the muscle glycogen storage.

In addition, the anabolic responses after exercise are regulated by the mTOR pathway too [10] and responses related to ATP generation are regulated by the AMP-activated protein kinase (AMPK) pathway [11] which is negatively regulated by glycogen availability and signaled in energy deficit and inhibit mTOR pathway [12]. In addition, the AMPK pathway responding to exercise intensity and acts as an intracellular signaler of energy status [13] besides conserving ATP content by activating catabolic signaling to restore cellular energy status [14] and to induce mitochondrial biogenesis in skeletal muscle [15]. Therefore, mTOR pathway which related to anabolic responses into the cell, undergoes changes when AMPK pathway is triggered by low energy availability and when there is a FFA greater intake by high fat diet or adrenaline induced by exercise. Although AMPK pathway is altered by CHO ingestion during exercise, both pathways, AMPK and mTOR, considering the FFA, need to be stimulated to adapt with strategies saving glycogen in low amounts of energy and subsequently potentiate the glycogen accumulation when in greater energy offerings.

The Carbohydrate Prescriptions Based on Exercise Time

The daily needs for fuel and recovery are based on training program and competitions. The amounts take into consideration exercise time, from low intensity or skill-based exercise to extreme exercise, which going to of 1 to 5 testing hours, respectively. For this, prescriptions can offer carbohydrate targets per kg of the player's body weight, going to 3 – 5 g until 10 – 12 g per kg each day, basically [16]. Another more recent model of carbohydrate prescription for endurance athletes brought the same models previously mentioned [17]. And more recently, another work brought the same amounts, but with a focus on optimal glycogen stores before competition, using taper activity for 3 to 6 days combined with 36 to 48 hours before test offering 8 to 12 g carbohydrates per kg [18]. That is, both are in accordance with the quantities. However, the most recent academy position brought focus on the carbohydrate's periodization at the before competition days. Another important fact is that the positions corroborate each other with carbohydrates offer before the competitions, with offering 1 to 4 g per kg eaten 1 to 4 hours before exercise [16-18].

Therefore, carbohydrate periodization prescribed based on the athlete's exercise time and on his training and game schedule, should obey amounts of hours preceding the testing. Strategies such as "normal diet" or "classic glycogen loading" employ carbohydrates linear consumption end up not getting cannot reach an overcompensation of muscle glycogen stores. Therefore, carbohydrates periodization in days leading up to the competition has been shown a strategy that increase the muscle glycogen stores and a "modified" consumption in the carbohydrate load has been a good strategy for this, applying a consumption in week before the competition of 5 g per kg each day from sixth to fourth day and from 8 to 12 g per kg each day for past three days, in addition 24 hours rest prior to competition [19-21]. The "sleep low" strategy consists a week of training with high intensity workout and high carbohydrate availability on late afternoon for to deplete muscle glycogen, followed a sleeping with low carbohydrates availability but with proteins ingested and in next morning a low intensity workout in low carbohydrate availability but with carbohydrates supply during practice, all this to boost metabolic adaptations that improve fatty acids and carbohydrates oxidation and increase muscle glycogen storage after carbohydrate refeeding in rest of the day causing a better performance at the competition day in end of the week [22-24].

The "train low, compete high" strategy consists in train with reduced carbohydrates availability obeying the practical concept of "fuelling for the work required" so can compete with high

carbohydrates availability, therefore being a potential strategy for to break train-low paradigms into periodized training programs with periodization carbohydrates strategies, turning this strategy into an interesting form of intervention to improve whole-body exercise capacity [25-27]. (Table 1) is a direct, summarized and referenced outline of the main practical applications of the carbohydrate periodization strategies with a description for better targeting when applying the athlete's practical prescription.

Table 1: Compiled from the main carbohydrate periodization strategies.

Strategy	Description	Response	References
Classic glycogen loading	3 days of high intensity training on a low-CHO diet (<5 g per kg body weight per day) followed by 3 days of tapered training on a high-CHO diet.	Supercompensation muscle glycogen stores in relation to before the intervention. Although, the training becomes difficult both physically and psychologically during the low carbohydrate ingestion.	[16–18]
Modified glycogen loading	3 days of high intensity training on a low-CHO diet (~2 g per kg body weight per day) followed by 3 days of tapered training on a high-CHO (8 to 12 g per kg each day) added to 24 hours rest before testing.	Induce a better supercompensation muscle glycogen compared to the classic loading regimen. Although, with the same problem classic loading regimen, the training becomes difficult both physically and psychologically during the low carbohydrate ingestion.	[19–21]
Sleep low	High intensity train with high CHO availability in the evening or late afternoon one week before competition, no CHO replacement neither pos-workout nor prior to sleep, but with proteins replacement, followed to low intensity train with low CHO availability in the netx morning with CHO load during this day, repeating the next evening or late afternoon.	The supercompensation of muscle glycogen stores occurs like the classic loading regimen. Although may exist the improvement on fatty acids and carbohydrates oxidation after carbohydrate refeeding in rest of the day after low intensity train. Therefore, the low intensity training is not so challenging due to its reduced intensity and this strategy is repeated and interspersed throughout the week that precedes the competition.	[22–24]
Train low, compete high	Consists to train purposefully with low CHO intake after an overnight fast and during and 2 hours pos high intensity train descrease CHO intake with the idea of promoting adaptations that result in glycogen supercompensation.	The train-low practice reduces the capacity to train hard and can harm the training capacity besides become train psychologically more challenging. Besides, there aren't clear evidence of additional benefits to glycogen stores or performance with comparing to sleep-low strategy.	[25–27]

Note: CHO, carbohydrates.

Conclusion

So, it is becoming complicated to assume a single strategy for one sport or even a single strategy for on athlete type. What is known is all strategies will have arguments for and against, will have seasons that better applicable and seasons that will not be able applied. This review brought recent and explanatory references with based on fundamentals behind the most used carbohydrate periodization strategies, as they are applied in practice and what strategy will benefit athlete's performance. What is up to the coaches, together with their athletes, is to define which strategy is best applied for that season, and the strategies presented in this review demonstrate an improvement in the performance of endurance athletes.

Authors' Contribution

The author is responsible to the study conception and design, including material preparation, literature review data collection, and analysis, besides read and approved the final manuscript.

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