Guru Performance Position Stand #2 – Fasted Training & Exercise Performance

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OVERVIEW

(1) INTRODUCTION

Our first Position Stand explored the efficacy of fasted exercise for the purpose of fat loss, during which we described various ways in which fasted exercise can be performed. A common theme among these methods is that they all require a certain degree of carbohydrate restriction in and around training, which as well as its potential for accelerating body fat loss, could also have favourable implications for exercise performance. As such, the purpose of this Position Stand is to address the significance of fasted exercise (in the form of carbohydrate restriction) through a slightly different lens – one which considers its potential for enhancing the 'strength' of the exercise stimulus, and ultimately exercise performance itself. Indeed, this is an exciting area of research that has grasped the attention of multiple research teams from all around the world; many of whom are striving to answer the same question: 'does strategically manipulating carbohydrate availability in and around training augment exercise performance?'. Herein we will provide an up-to-date summary of the available literature, and contextualise the research to help inform practice. Specifically, we will look at the practicality of carbohydrate restriction in and around exercise, and give our thoughts on whether athletes should consider incorporating this type of strategy within their training regime with a view to improving performance.

(2) FASTED TRAINING AND EXERCISE PERFORMANCE – WHAT THE RESEARCH SAYS

For many years high carbohydrate availability has been regarded as a key determinant of exercise performance (for review see Cermak and Van Loon, 2013) and, as such, many athletes have intuitively resorted to consuming high carbohydrate diets. However, and somewhat paradoxically, an emerging body of evidence suggests that periodically and strategically restricting carbohydrates in and around training could increase the strength of the exercise stimulus and exercise-induced training adaptations, which in theory could translate to an improvement in exercise performance. This is an attractive proposition to many athletes and their coaches, particularly when one's training load is fully saturated. In this respect, training with reduced carbohydrate availability could be a means of 'training smarter' and further enhancing the determinants of performance. So, what does the research say…

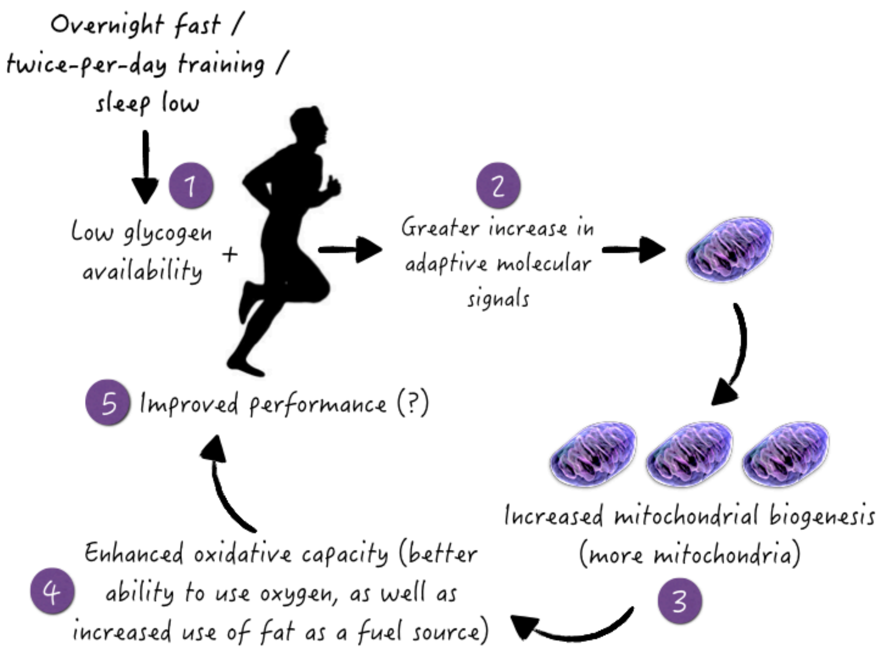
Firstly, it is important to be aware that the idea of manipulating carbohydrates in and around training isn't new! In research terms, we can trace it back to the 1960's. The landmark study that got people thinking about carbohydrate manipulation around exercise came from the legendary sport scientist, Bengt Saltin and his research team (Bergström et al., 1967). However, it wasn't until the early 2000's when an idea emerged based on Bergström's work that if muscle glycogen (the bodies storage form of carbohydrate) is so important for exercise performance, then could training with reduced carbohydrate (and thus glycogen) availability force an 'extra adaptive response' that is above what can be achieved when carbohydrates are available? Indeed, future work then went on to show that when exercise commences with low muscle glycogen, the genes associated with endurance exercise adaptation are enhanced above those achieved by performing the same exercise bout in a glycogen replete (carbohydrate fed) state (Pilegaard et al., 2002; 2005). This opened up a new wave of research that sought to determine whether these augmented 'molecular signals' translate to more meaningful changes in the metabolic make-up of the muscle and, most importantly, exercise performance. So how did these pioneers do this in the lab?

The 'twice-per-day' training model was the first to identify metabolic benefits of training with reduced carbohydrate availability (often referred to as 'training low'). It involves performing repeated exercise sessions with low glycogen availability and was first executed in the lab using a two-legged knee extensor model. Similar to what you find in most gyms, the participants were seated on a knee extensor machine (used to train the quadriceps) and performed a simple repeated kicking exercise (one hour @ 75% peak power). One leg was trained twice every other day whilst the other leg trained once every day for a total of five days per week for ten weeks (so by the end both legs had done the same absolute amount of work). By restricting carbohydrates between the twice-per-day sessions, the second session was commenced with low muscle glycogen that had been depleted by the first session. After extracting small amounts of quadriceps muscle for analysis, the researchers found that resting muscle glycogen, enzymes involved in oxidative metabolism and importantly, exercise capacity were improved to the greatest extent in the twice-per-day (low glycogen) group. These results were really exciting for scientists and coaches alike, but questions were asked about the pragmatism of a knee extensor model. Surely, study designs using whole body exercises commonly used in training programs would be more appropriate? We certainly don't know coaches that implement one-hour of knee extension in a training program! Nevertheless, this study provided an excellent, and all-important, initial insight.

Interestingly, follow-up studies using whole body exercises were able to confirm the superior effects of this training model on various metabolic enzymes both in their abundance and activity, as well as an increased capacity to oxidize (burn) fat as a fuel source during exercise (Hulston et al., 2010; Morton et al., 2009; Yeo et al., 2008). For example, Morton et al (2009) employed six weeks of high intensity running training consisting of two sessions per day, two times per week during which carbohydrates were either fed or restricted (in the form of a placebo to eliminate design bias). The group that exercised with low carbohydrate availability during the training program demonstrated significantly greater increases in oxidative enzyme adaptations (markers of oxidative capacity). However, in these papers it was noted that one potential issue with this approach was that the intensity at which one was able to perform the second exercise session was often reduced (typically by around 7-8%), which of course is a large difference and a side-effect that is certainly worthy of consideration by athletes and their coaches. A parallel with this, van Proeyen and colleagues reported similar results when training was commenced after an overnight fast i.e., exercising in the morning time before breakfast (van Proeyen et al., 2011). As with twice-per-day training, overnight fasted exercise led to decreased glycogen breakdown and greater increases in metabolic enzymes, as compared with training in a carbohydrate replete state.

Finally, following these twice-per-day paradigms came the 'sleep low/train low' method, which essentially combined the prior approaches to training low (Bartlett et al. 2013). Specifically, those that took part in this study completed an evening high intensity interval training (HIT) session to deplete muscle glycogen and didn't consume any carbohydrates after the session. Participants then went to sleep and performed a subsequent HIT session the following morning. As such they had 'slept low', meaning they had spent a prolonged period in a carbohydrate-restricted state, following which they 'trained low' the next morning. This novel approach resulted in superior exercise adaptations as compared with performing the same exercise bout with carbohydrate provision. In theory such findings could be interpreted to mean that sleeping low enhances the adaptation to exercise, at least for high intensity interval training.

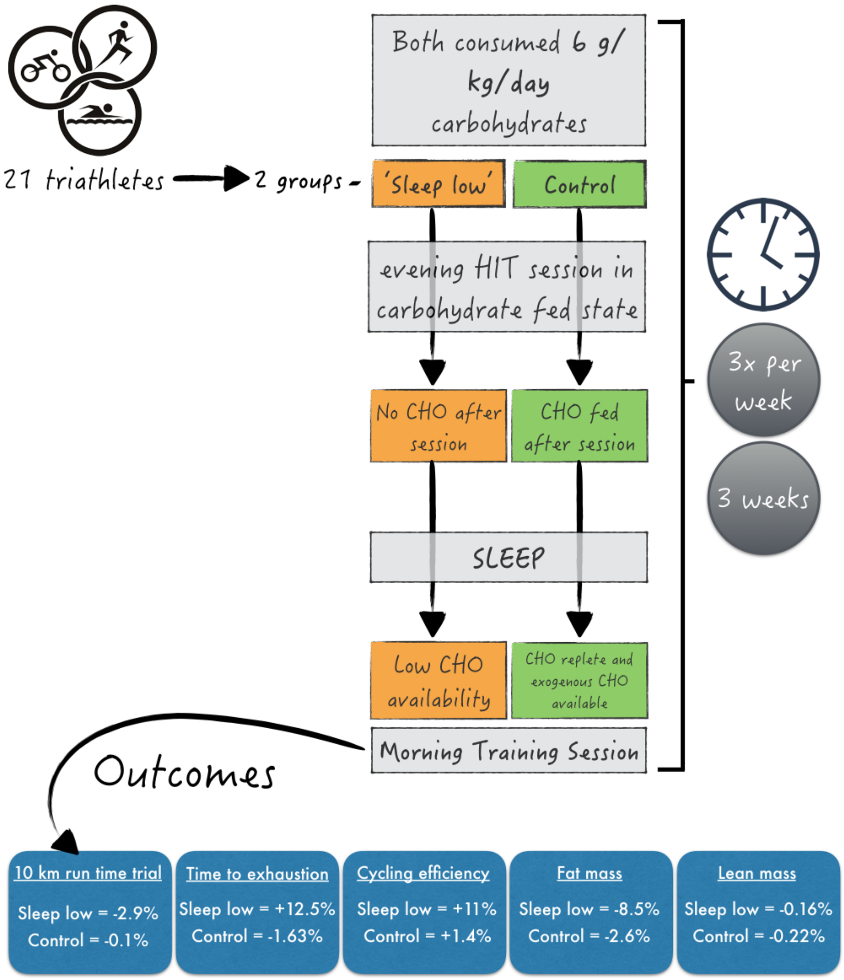
To summarise at this point, what most of these studies have assessed as 'beneficial adaptations' induced by training low have been the signals associated with mitochondrial biogenesis, such as the expression of genes that are known to lead to the production of new mitochondria and also the abundance and activity of metabolic enzymes. In brief, mitochondria are the engines of muscle cells - the place where fuel is used to produce energy required for muscle activity. So, if the muscle has more mitochondria it can produce energy more effectively and efficiently during exercise, which in theory should help to maximise performance. We have created a simplified diagram below to help illustrate this.



From a practical standpoint, the key question posed by athletes and their coaches is whether these enhanced molecular adaptations transfer to a meaningful improvement in exercise performance itself. Indeed, the tools and techniques used within the lab to measure enzymes, proteins and genes have high variability and in many instances this exceeds the very small biological changes that translate to improved performance. To appropriately assess whether these adaptations transfer into a significant performance benefit requires a series of well-controlled longitudinal studies investigating the impact of exercise training in the fasted versus non-fasted state on muscle metabolism and crucially, exercise performance itself. Unfortunately, only a handful of studies have provided such insight and the findings appear to be mixed…

In the overnight fasting study by van Proeyen et al (described earlier), both the fasted and fed groups had comparable improvements in VO_{2max} and total work done during a one-hour time trial, meaning that the metabolic benefits of regular fasted exercise did not equate to a performance benefit above that seen when carbohydrates were fed in and around exercise. Similarly, a trial conducted by Yeo et al. (2008) showed that power output during a 60-minute time trial was similar between both the 'train low' and 'train high' carbohydrate groups, despite observing greater muscle metabolic adaptations in the 'train low' group.

On the contrary, one more recent study which came via the French Institute of Sport, Expertise and Performance (INSEP) implemented the sleep low method around selected training sessions over a three-week training period in a group of well-trained triathletes (VO_{2max}: 58.7 ± 5.7 mL/min/kg). Specifically, this study split the cohort of 21 triathletes into two groups: (1) sleep-low, and (2) control. Both groups consumed the same total amount of carbohydrates (6 g/kg/day), but at different times throughout the day (to manipulate CHO availability before and after the training sessions). This study design is the closest to real world practice that has been reported and interestingly the researchers demonstrated that the triathletes in the sleep low group demonstrated greater improvements in 10 km time-trial running performance, cycling economy, and body composition as compared with the control group who regularly consumed carbohydrates before and during training (Marquet et al., 2016; see diagram below). Studies such as the INSEP trial are absolutely essential for us to be able to extrapolate research findings and apply them with a certain degree of confidence into applied practice. More investigations like this are needed and we anticipate that this work has raised the bar for research teams who will go on to assess the worthiness of carbohydrate manipulation in and around exercise for athletes.



(3) KEY CONSIDERATIONS WHEN EVALUATING THE AVAILABLE RESEARCH

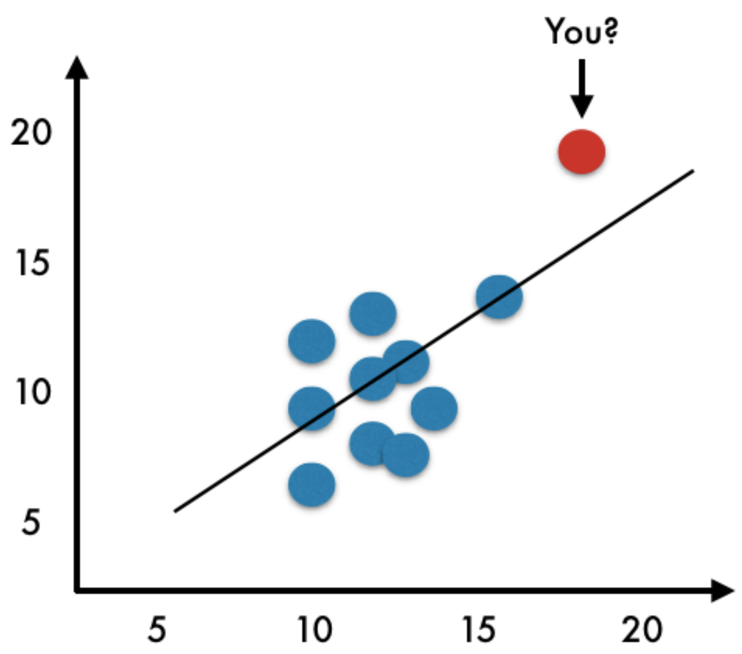
Laboratory-based performance studies versus real world performance: It is very important to appreciate that the laboratory-based performance studies may not have been sensitive enough to detect meaningful physiological changes that would be highly relevant to real world performance. In other words, there may be a very small, and physiologically meaningful improvement in performance but the lab trials (i.e. those that assess performance using time-trials or time to exhaustion tests), are not sensitive enough to pick those up. It's also important to note that statistical significance for a journal versus physiological significance for an athlete are two very different things and is likely to be much larger than what we think it is in the laboratory. To put this into perspective, the mean difference between 1st and 4th place at the London 2012 and Sochi 2014 Olympics was 0.4% - a difference that may fail to reach statistical significance in the laboratory setting, but is highly meaningful in the real world performance setting (i.e., it is the difference between medalling and not medalling!).

"Statistical significance for a journal versus physiological significance for an athlete are usually two very different things"

Study design: We must also remember that the design of laboratory protocols very rarely reflect the training program design of elite athletes. For example, the studies that we have discussed earlier all use a model where either 50% or 100% of the exercise sessions are performed in a carbohydrate-restricted state (with the exception of the study by Marquet). This simply does not reflect the training strategies of most elite athletes where maybe 1-2 of their sessions performed over a week are completed in a carbohydrate-restricted state. Moreover, similar to the training program design, this is unlikely to be a repetitive pattern over the season and might only be utilised during certain cycles. Training programs are complex and periodised in which different sessions have specific goals. Considered collectively, it can be easy to forget the real world context when reading research papers, but it is paramount to understand what the goals of each training session are for the athlete in order to determine whether sessions should be performed in a carbohydrate restricted or fed state.

We don't work with means, we work with individuals: Elite athletes differ immensely in their physiological and psychological profile as compared with the majority of participants typically involved with laboratory-based research studies (usually recreational or well-trained athletes). What's more, it is common for research papers to cite means (the average finding based upon a group of individual results), yet in the real-world we don't work with means, we work with individuals – and in the case of elite athletes these individuals often defy what we believe is even possible. As such, one should be cautious when extrapolating research findings (particularly grouped data) for use with their athlete, who could be the outlier!

"We don't work with means; we work with individuals. Often in the case of elite athletes, these individuals are the outliers"



Elite athletes are almost always one step ahead of the game: Many of us look to the research papers for direction as to how we can maximise performance of the athletes we're working with. However, it's worth noting that athletes are often one step ahead of the curve! That is, training with reduced carbohydrate availability has been implemented (perhaps sometimes inadvertently) for many years by boxers and endurance athletes from all around the world, who typically perform select 'water only' sessions. We can and must listen to the athlete to extract the most valuable information, that we can then test and perfect to maximise their responses to training; hence why we hold 'research engaged practice' in very high esteem!

(4) POTENTIAL LIMITATIONS TO PERFORMING FASTED EXERCISE WHEN TO GOAL IS ADAPTATION

Our first Position Stand (Fasted Exercise and Body Composition) addressed three potential limitations to fasted exercise, these being: (i) its influence on training intensity, (2) its influence on immune function, and (iii) its influence on muscle mass. Here we also offered practical tips to help offset these potential limitations and would encourage readers to familiarise themselves with these, which are also relevant when the goal is exercise adaptation and performance.

As well, we would like to stress that purposely restricting carbohydrates over a prolonged period of time (i.e., repetitively training fasted or following a low carbohydrate, high fat diet) could lead to a shortfall of energy during competition itself, particularly if the event requires multiple high intensity efforts. Allow us to expand…

As we have already mentioned, restricting carbohydrates in and around training could lead to greater exercise-induced training adaptations and, as a by-product of such adaptations, increase the reliance on fat as a fuel during exercise. Indeed, fat is an abundant fuel source (even a lean person of ~body weight 70kg stores around 90,000-140,000 kcal of fat – sufficient to allow a person to walk ~16,000 km), whilst carbohydrate stores are limited (~1,800 kcal to 2,500 kcal in a fed state). Therefore, increasing the reliance on fat as a fuel during exercise could be viewed as a favourable adaptation as it will help preserve limited carbohydrate stores and possibly extend time to fatigue. To some extent this is true, however one should also be cognisant that repetitively training fasted / restricting carbohydrates could limit exercise performance by hampering the body's ability to utilise carbohydrate, which is the key energy source for high intensity efforts.

Specifically, studies have shown that five days of carbohydrate restriction significantly reduces the ability of the body to: (1) tolerate and absorb carbohydrates, (2) break down stored carbohydrate in the muscle (via a reduction in glycogenolysis; and (2) transport carbohydrates through to the muscle mitochondria (via a reduction in PDH activity). Interestingly, these effects persist even when carbohydrates are fed the day before exercise. It could be argued that in these studies five days was not long enough to 'fat adapt' the athlete, however to our knowledge there is only one study (Phinney et al. 1983) that 'fat adapted' athletes for one month. The sample size was very low (n=5) and the performance findings were far from clear (two people improved their <u>sub-maximal</u> exercise-performance, one stayed the same and one got worse).

The take home message here is that whilst increasing the capacity to utilise fat during exercise could be beneficial (as it will help preserve the bodies precious carbohydrate stores), fat is a less efficient fuel source as compared with carbohydrate. As such, high performance athletes who chronically restrict carbohydrates are likely to have a shortfall of energy during competition, particularly if their event requires high intensity efforts.

"Chronically restricting carbohydrate will significantly reduce the body's ability to use it as a fuel source"

In example: an athlete who chronically restricts carbohydrates and subsequently doubles their capacity to use fat as fuel during exercise (maximal fat oxidation increases from 0.75 g/min to 1.5 g/min) would burn ~810 kcal / hour of exercise (1.5 g/min x 60 min x 9 kcal/g). However, world class marathoners require 1,200-1,500 kcal / hour to complete the race. So, consistently training with reduced carbohydrate availability for the purpose of increasing the capacity to use fat during exercise is likely to reduce the overall intensity at which one can perform exercise (as their ability to use carbohydrates will be impaired). On the flip side, somewhere around 4-4.5 hours of marathon running can be done at 810 kcal / h, so for the non-elites it's an interesting paradigm. However, for the elite athletes that want to go to the Olympics and perform at the top level – shutting off their ability to use carbohydrates as fuel will strip away gears 4, 5 and 6 and likely leave them at the back of the pack. From a biochemistry and physiology standpoint, it seems counterintuitive for elite athletes to shut off their ability to use carbohydrates during exercise. Ultimately, the goal should be 'metabolic flexibility' – that is, to prime the body to use both fuels (carbs / fats) as and when required. Dietary extremes, such as chronically restricting carbohydrates / fats etc., are dangerous and should be avoided as they have no place in contemporary sport nutrition guidelines.

"Athletes need to be able to switch between carbohydrate and fat for fuels. There is no point in an athlete having a 5th and 6th gear if they cannot use them"

(quote from the Guru Performance 'We Do Science' Podcast, Episode 45 with Trent Stellingwerff PhD)

(5) PRACTICAL CONSIDERATIONS

- **The research:** There is good hypothetical research in support of training with reduced carbohydrate availability to enhance exercise-induced training adaptation, and there is emerging data to suggest this could have a physiologically meaningful influence on exercise performance. As such, strategically and periodically restricting carbohydrate intake in and around training could help to achieve an extra performance advantage, which could be the difference between winning and losing / medalling at the Olympics and not medalling.
- **You can do it, but should you do it?** We would encourage those who are contemplating this method to first ascertain where on the scale of relevance manipulating carbohydrate availability fits in, such that they can determine whether they qualify for it. For instance, we believe that this approach is only relevant to certain people in certain scenarios i.e., it should be considered by elite athletes who are looking to 'fine-tune' performance, already acquire a strong physiological base and have the appropriate knowledge to implement the method. On the contrary, this method is unlikely to induce a meaningful impact upon the performance of elite or recreational athletes who do not possess such attributes. For these individuals, it would be far more important (and impactful) to first of all focus on getting the basics right, and refining their approach to training and nutrition later on. In other words, you have to bake the cake (master the basics of training and nutrition) before putting the sprinkles on (consider specific training and nutrition strategies such as 'train low').
- **Fuel for the work required:** If one is to consider restricting carbohydrates in and around training then they should be aware that this approach might help them adapt in one way (i.e., increase exercise-

induced training adaptations), but this should not come at the expense of the other characteristics that are also important for performance (i.e., the ability to tolerate, absorb and utilise carbohydrates), the required intensity of the training session, psychological mood state, sleep etc. We would encourage athletes who wish to deploy such a strategy to adopt a 'carb smart' approach to training and strategically periodise their carbohydrate intake according to the aims and demands exercise session i.e., to fuel for the work required. One approach could be to restrict carbohydrates during select training sessions (i.e., those which focus on aerobic metabolism and the capacity to utilise fat as fuel), but consume some carbohydrates in and around high intensity sessions. This would help to enhance various aspects of metabolism and promote metabolic flexibility. The aforementioned limitations to training with reduced carbohydrate availability should also be considered and the necessary practical solutions implemented where possible.

(6) FUTURE RESEARCH

- We look forward to seeing more performance based studies in this area, which will help to provide greater resolution on the efficacy of strategically and periodically restricting carbohydrates in and around exercise for performance optimisation.
- Another logical step would be to explore practical ways of applying this approach into the macro-cycle of the athletes training programme. Indeed, Marquet et al (2016) provide the first step towards this but we are far behind a complete real-world study utilising a periodised training programme for professional athletes.
- It would be important to determine which type of training session and approach to carbohydrate restriction is best at augmenting adaptation and performance. Should fasted exercise be targeted towards low intensity sessions following a glycogen depleting high intensity session? Is overnight fasting, sleep low, twice a day models, or perhaps a combination of these methods most powerful? Future work is likely to address these important practical questions.
- Finally, it would also be necessary to determine sex-based differences in the response to training with reduced carbohydrate availability, and its subsequent impact upon exercise performance.

(7) CONTEXT STATEMENT

Fasted exercise is not a magic bullet that will rapidly and remarkably improve exercise performance, but could be worthy of consideration by elite athletes who are looking to maximise performance and gain that extra performance advantage. We are firm believers that sports nutrition is not black or white and that being at the extreme end of carbohydrate intake or restriction (and similarly for any other nutrient) for a prolonged period of time is dangerous and should be avoided. Instead, we believe that it's all about degrees of moderation, and encourage athletes to adopt a 'carb smart' approach to training such that they are metabolically flexible and able to meet the demands of their sport.

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