2.2 Training Low and Periodising Nutrition

2.2.1 Training twice a day

We discussed the concept of "training low": training with low carbohydrate availability. There are many ways to achieve this, but in the literature, training twice a day is the most studied method. The method was first used in a study by Hansen et al. (2005), who used a one-legged kicking model (knee extensions) to compare training daily: once a day versus twice a day (see Figure 2). On the days when subjects trained twice, the second exercise bout was performed with low muscle glycogen. Therefore, subjects trained half the time with low muscle glycogen and the other half with normal glycogen. In the control trial where subjects trained once a day, glycogen stores were always replenished. Training with low glycogen half the time produced marked improvements in markers of oxidative capacity (for example, the investigators saw an increase in the activity of the enzyme 3-hydroxyacyl-CoA dehydrogenase and citrate synthase (CS)) in muscle, as well as an increase in muscle glycogen compared with training in a glycogen loaded state all the time (Hansen et al., 2005). Coaches started implementing this immediately, but some scientists were not convinced because the mode of exercise was far from a real-life situation.

There were other questions as well: the study was performed in untrained individuals, but would this also apply to already trained individuals? The studies were therefore followed up by a series of other studies. We performed a study in the United Kingdom and at the same time a study with an identical design was started in Australia. Both Hulston et al. (2010) and Yeo et al. (2010) investigated the effects in far more realistic settings. The leg kicking model was replaced with cycling exercise. In both studies, cyclists trained twice a day, every other day or once every day. When training twice a day, they only consumed a minimal amount of carbohydrate between the two sessions. After 3 weeks, the effects were studied and it was reaffirming to see that both studies produced very similar results.

> The first observation in both studies was that the cyclists who trained twice a day (train-low group) could not maintain the same intensity as the cyclists who trained once a day (train-high group). Despite the fact that the former performed less work, some of the adaptations were

> greater. For example, Hulston et al. (2010) reported that "hydroxyl-acyl CoA dehydrogenase (HAD) and CD36 protein content was increased more with train-low" and fat oxidation rates were greater too (Hulston et al., 2010; Yeo et al., 2010). Another independent study by Morton et al. (2009) also observed similar beneficial adaptations (increased succinate dehydrogenase activity) when training with low muscle glycogen. (Jeukendrup 2017a, https://bit.ly/2W08dX0)

So, it appears that some training in a low glycogen state (in this case, 50% of training) can result in greater adaptations at the muscle level than training with high glycogen all the time. The adaptations observed were mostly related to increases in mitochondrial capacity and the capacity to oxidise fatty acids.

However, the studies also measured performance and no improvements were seen in it. It is likely, though, that this is because of the relatively short duration of the study and the fact that subjects were already trained at the start of the study. The performance improvements that could be expected were small and improvements may take much longer than in untrained populations.

In football, it is not unusual to train twice a day, although often one of the two training sessions is a strength workout and often training twice a day is limited to off season. In the studies discussed above, the train low sessions were performed in the afternoon and the mode of exercise was intermittent exercise training. The morning session was aerobic training of a lower intensity. When combining different workouts (concurrent training), one has to be aware that the outcomes of these workouts could be compromised by combining them. A recent study showed that various measures of anaerobic power were compromised by performing resistance training and endurance training on the same day (Shamim et al., 2018). It is beyond the scope of this section (and course) to discuss the effects of concurrent training. But there are a number of good reviews: Coffey and Hawley (2017); Fyfe, Bishop, and Stepto (2014); Perez-Schindler et al. (2015).

In conclusion, it appears that training twice a day may result in adaptations that favour fat metabolism but it is too early to definitely conclude that this training method will also result in long term performance benefits. There may be applications in football, but, probably, as part of dual training sessions already being planned.

2.2.2 Training fasted

Perhaps the most common way to "train-low" is training in an overnight fasted state or training without breakfast. Typically, the last meal is consumed between 8 and 10 PM the night before, and exercise is performed in the morning before breakfast is consumed. For some football players, this may be the preferred way to train anyway. However, it is often believed that "breakfast is the most important meal of the day". This wisdom has very little scientific backing. Of course, making sure liver glycogen stores are full may enhance endurance capacity and could help performance during harder and longer training sessions. However, often training is not that long or not that hard and training in a fasted state would be acceptable and may even have some advantages from a metabolic point of view.

Training in a fasted state is different from the previous method of training twice a day where muscle glycogen was reduced by prior exercise. When training fasted, muscle glycogen should be unaffected by the overnight fast, but liver glycogen will be very low (Nilsson & Hultman, 1973). Studies by Peter Hespel and co-workers (De Bock et al., 2005; Van Proeyen, Szlufcik, Nielens, Ramaekers, & Hespel, 2011) have demonstrated that training in the fasted state may induce more profound adaptations then training after a carbohydrate containing breakfast and consuming carbohydrate during exercise. For example, in one study it was demonstrated that oxidative enzymes like CS and HAD were upregulated to a greater degree (47% and 34% respectively) when fasted was compared with fed after 6 weeks of training (4 x per week, 1-1.5h at 75% maximal oxygen uptake (VO_2max)) (Van Proeyen, Szlufcik, et al., 2011). The authors concluded that training in the fasted state was more effective to increase muscle oxidative capacity than training in the fed state. They also observed that intramuscular fat utilization was increased with fasted training and improvements in the regulation of blood glucose concentrations.

The mechanisms are likely to be different from training with low muscle glycogen. Van Proeyen, De Bock, and Hespel (2011) found no differences in AMPK in subjects training in the fasted state versus fed, but did observe differences in post exercise eukaryotic elongation factor 2 (eEF2) phosphorylation (elevated after carbohydrate feeding but not after fasting). De Bock et al. (2005) showed that exercise in the fasted state facilitated IMTG use during

exercise and improved glycogen resynthesis. It was also demonstrated that carbohydrate ingestion blunted uncoupling protein 3 (UCP3) gene expression whereas training in the fasted state resulted in a marked increase in UCP3 gene expression (De Bock et al., 2005).

Not all studies showed the same positive effects of training in a fasted state. Another study by the same research group did not result in any marked improvements (De Bock et al., 2008). In this study small changes were observed in proteins involved in the regulation of fat metabolism, but this did not result in measurable changes in fat oxidation. Overall, the results of these studies are promising and there appear to be potential benefits of training in the fasted state (Jeukendrup, 2017a). However, there are still a number of practical questions that need to be answered such as how many days of training per week are needed? What is the type of training (intensity and duration) that is most suitable for fasted training? How many weeks should this training be performed to see meaningful effects? In addition, studies so far have focused on metabolic adaptations and few have addressed potential effects on exercise performance. Will training in the fasted state result in performance improvements over time? (Jeukendrup 2017a, https://bit.ly/2W08dX0)

One lesson we can learn from these findings is that the "breakfast is the most important meal of the day" has little scientific foundation. So, players who prefer training with little or no breakfast should probably be allowed to do this on days where this is appropriate. On days when training quality needs to be high or on days when there is a strong focus on recovery, this may not be appropriate and these players should be encouraged to have a carbohydrate rich breakfast. Once again, there is no one size fits all.

2.2.3 Planning the year

So far, we have discussed a number of goals a football player may have throughout the seasons and we also discussed how we can support these goals with nutrition. For example, the following topics we covered are important for periodising nutrition through the year: weight loss strategies, or weight gain (muscle mass) strategies, supplement use and rapid recovery versus training adaptation.

Step 1: Get the overview of all match days for a whole season, including friendlies.

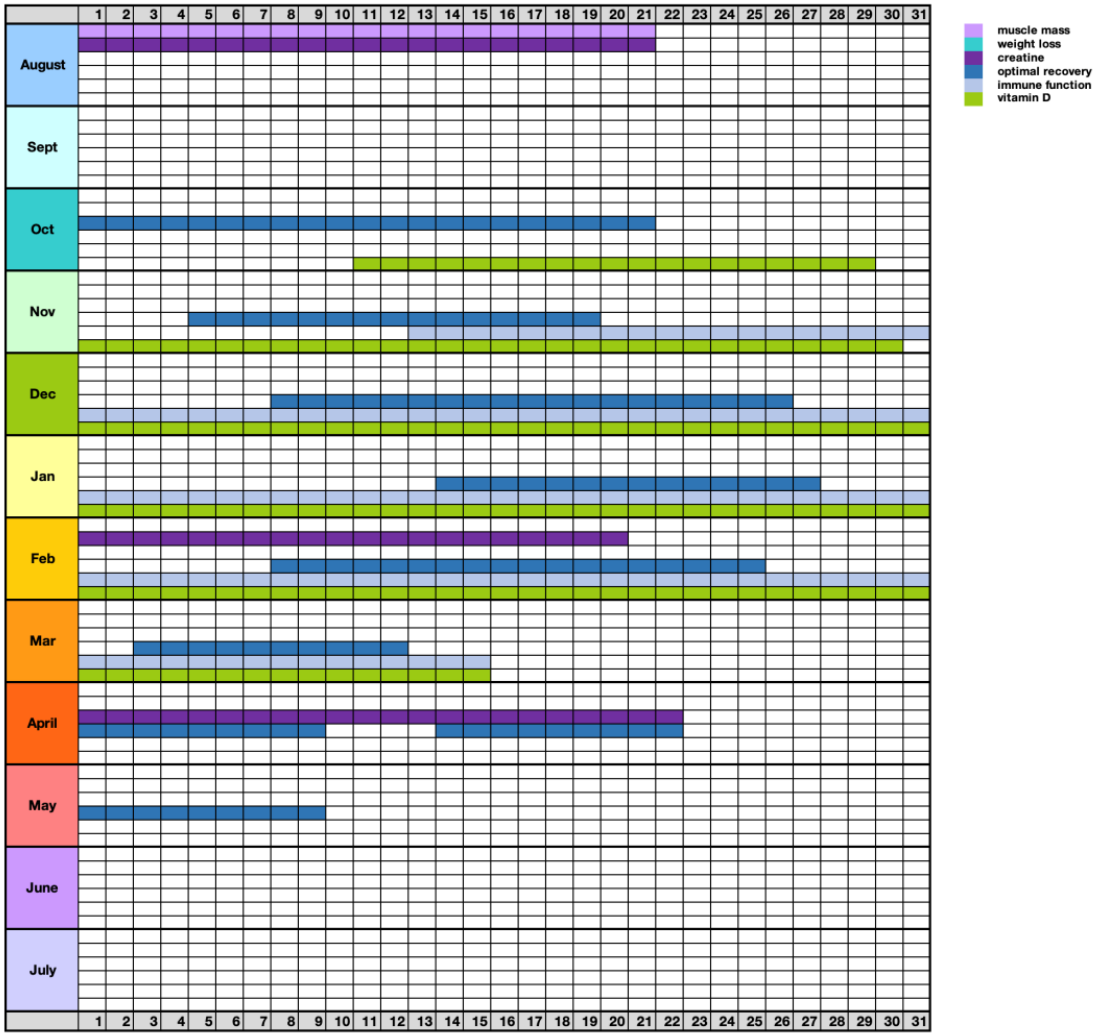
Step 2: Sit down with coach/training staff and ideally also with medical staff and the player to discuss what the main training goals are for each individual.
Step 3: Develop a generic plan for all players that can be adjusted to the individual player.
Step 4: Sit down with each player and discuss the nutrition plan, training plan, and supplementation plan. Adjust where needed.

In these discussions make sure that at least the following topics are covered:

- In what phase or phases of the year is recovery critical?
- In what phase or phases of the year is there an emphasis on conditioning?
- Is weight loss important? If so, in what part of the year?
- Is increasing muscle mass important? If so, in what part of the year?
- Determine when immune function might need extra attention
- Determine when to start with vitamin D supplementation
- Determine if and when creatine supplementation should start
- Same for other supplements that are deemed important

Once you have the answers to these questions, you can start to work these into the yearly calendar. What you should end up with is a yearly plan that looks like this:

Figure 4: Example of a year planning for nutrition for a football player



Source: Source: prepared by the author.

This is just an example and this plan will be different for most players because goals and preferences are different.

In this particular example, weight loss was not an issue and there is focus on weight gain only for a very short period of time. Creatine is cycled with a few “on” periods before important parts of competition and some “off” periods when creatine concentrations are still high from the previous round of supplementation. Each player will have his own calendar and it is important to have a good communication system and a good system to share information, so that the player but also the staff knows when to do what. There are many ways to communicate this effectively with players. Manual and automated text message systems, many clubs have their own communication channels or even apps. There are also nutrition analysis software packages that include a communication function. It is probably best to trial some of these options and see what works best. It

is important to view this communication system through the eyes of the player: how can this be used in a way that it clear and easy for the player.

In this yearly plan, education sessions can be built in as well as well as talks. For example, it is a good idea to remind everyone of the role of vitamin D before starting the supplementation. Cooking classes, shopping classes or education sessions with wives, girlfriends and family should all be part of the year planning. Various tests should be part of this schedule too. Blood tests, sweat tests, fitness tests, if they have relevance to nutrition. Everything that has an impact on nutrition strategies should be part of this comprehensive year plan. Of course, a plan is only a plan and it is impossible to predict what will happen during a long season: a player may get injured and goals may change. The plan then needs to be adapted accordingly, but it is important to always have this plan and not become reactive.

In a year plan, some aspects are generic (they are the same for all players), and some parts are highly individual. For example, some education sessions may be for everyone, vitamin D supplementation may start on the same day and end on the same day for everyone. But there may still be individual differences: vitamin D supplements may be given out in different doses depending on skin colour (darker skin requires higher dose to get the same effects) and some aspects are completely individual. For example, some players may want to use creatine and others may not. It is worth planning the year carefully and discussing these plans with the player and staff to get commitment from all. Most importantly, having this plan creates clarity and helps to get the vision across.

2.2.4 Planning the week

Training and competition can vary considerably from week to week. The training goals may vary, there may be more or less traveling, there may be 1 and up to 3 matches within a 7-day period. Therefore, nutrition planning will be different as well. Each week can be planned in advance, and periodised according to the goals of that week and where needed personalized to the individual.

Although most work on periodised nutrition has probably been done on endurance athletes and in particular cyclists (Figure 5), football has received a lot of attention too (figure 4).

Figure 5: Theoretical overview of the 'fuel for the work required' model

	CHO Feeding Schedule			
Training Session	**Pre-Training Meal**	**During Training**	**Post-Training Meal**	**Evening Meal**
Day 1: 4-6 hours high-intensity session consisting of multiple intervals >lactate threshold	**HIGH**	**HIGH**	**HIGH**	**LOW**
Day 2: 3-5 hours low-intensity steady state session at intensity < lactate threshold	**LOW**	**LOW**	**HIGH**	**HIGH**
Day 3: 3 hours high-intensity session consisting of multiple intervals > lactate threshold.	**HIGH**	**MEDIUM**	**HIGH**	**MEDIUM**
Day 4: < 1 hour recovery session at intensity <lactate threshold	**LOW**	**LOW**	**HIGH**	**HIGH**

Source: Impey et al. 2018, https://bit.ly/2HdC6A8.

Figure 5 An example of a week for an elite endurance athlete (e.g. road cyclist) who trains once per day on 4 consecutive days where each session commences at 10:00 am each day. In this example, the athlete has four main feeding points and the CHO content of each time point is

colour coded according to a red, amber or green (RAG) rating that represents low, medium and high CHO intake. Note that we have not prescribed specific CHO quantities and deliberately chose a RAG rating so as to highlight the necessity for flexibility in relation to athlete history, training status and specific training goals, etc. Rather, the model is simply presented to illustrate how train-low paradigms can be amalgamated to adjust CHO availability day-by-day and meal-by-meal according to the demands of the specific training session across the 4-day training block. In this example, high CHO intake is advised before, during and after the training session on day 1 (e.g. 'train high'), but reduced in the evening meal to facilitate sleep low and train low for a lower-intensity session on day 2 (i.e. likely commenced with reduced muscle glycogen and withholding or reducing CHO content of the pre-training meal). Following completion of the second training session, high CHO availability is prescribed for the remainder of day 2 so as to promote glycogen storage in preparation for a higher absolute workload and intensity on day 3. Given that day 4 is a designated recovery day of much lower duration and intensity, CHO intake is then reduced in the evening of day 3 and breakfast of day 4, but is then increased throughout the remainder of day 4 in order to prepare for another 4-day training block. The model should be adjusted according to the number of feeding points and training sessions that are to be undertaken on each day. Careful day-to-day periodisation in a meal-by-meal manner (as opposed to chronic periods of CHO restriction or CHO feeding) is likely to maintain metabolic flexibility and still allow the completion of high-intensity and prolonged duration workloads on heavy training days, e.g. interval-type sessions undertaken above lactate threshold. Intuitively, 'train low' may be best left to those training sessions that are not CHO-dependent and where the intensity and duration is not likely to be compromised by reduced CHO availability (e.g. steady-state-type training sessions performed at intensities below the lactate threshold). Additionally, the model may also provide a framework to aid body mass loss given that train-low sessions on lower-intensity training days may allow for the creation of energy deficits without negating training intensity. Impey et al. 2018, https://bit.ly/2HdC6A8.

The two most important variables that will need to be periodised are carbohydrate and energy. Protein is the most constant of all

macronutrients and fat will make up for the remaining energy requirements after the carbohydrate and protein needs are met.

The main focus the days leading up to a match may be on optimising glycogen stores and, as we discussed above, these are some of the key recommendations for carbohydrate intake:

- Daily carbohydrate intake should be 5-8 g/kg/day depending on daily activity.
- This should be achieved by lowering fat intake, but keeping protein intake relatively high.
- The types of carbohydrate do not matter that much.
- The timing of intake is important if recovery time is short, and glycogen restorations should be started by ingesting carbohydrate the first hour after exercise. If recovery time is long, timing is less critical.
- On match days, fibre intake should be a little lower, especially in those players that often experience gastro-intestinal discomfort. On other days, especially on rest days, fibre intake may be increased.

Regarding protein intake, the goals are more constant. Each meal should contain 20-25g of high quality protein and meals should be taken 3-4 hours apart from each other to optimise protein synthesis.

There are a few different categories of meals that can be used to periodise nutrition during a week:

1. Meals that are low in energy, relatively low in carbohydrate, but high in fibre. There is a focus on healthy eating and these meals are not too different from the guidelines for normal healthy eating.
2. Meals that are higher in energy (carbohydrate) but have a protein focus. These are meals that could be used around strength training or any training that is not glycogen depleting.
3. Meals that are high in energy and, in particular, carbohydrate. These are generally larger meals and, although there is still a good amount of protein in these meals (>25 g), the focus is on carbohydrate. These meals are used in preparation for a match and recovery from matches or hard training.

The procedure for planning the week could be:

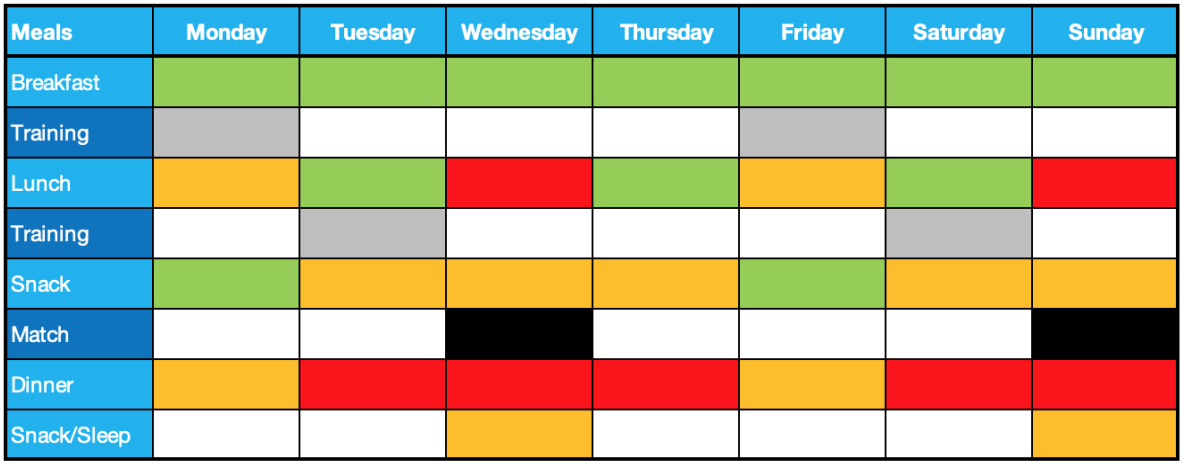
1. Having a discussion on a set day with the trainer/coach to understand the training goals and objectives for match day and the rest of the upcoming week. Having an understanding of the demands of each session, especially with respect to

carbohydrate needs: are these low, medium or high on each of the days.

2. Developing a theoretical nutrition plan that supports all nutrition goals and will keep players with an energy and carbohydrate balance, and at the same time provide sufficient protein in all meals. This will also require you to define what low, medium and high from the previous point is.
3. If there is a chef, plan the meals with the chef to make sure all the goals of the theoretical plan are met.
4. Think of solutions for the meals that cannot be controlled within a club environment. You can work with the families, wives and girlfriends of players and help them prepare appropriate meals.
5. Make sure that, especially for the meals around the match, there is a clear plan.

Figure 6 is an example of a periodised week for a team that plays two matches per week. One on Wednesday night and one on Sunday (indicated in black). Training is indicated in grey. Monday is an easy day and lunch and dinner provide a fair amount of carbohydrate, but breakfast and snacks on that day are relatively low carbohydrate, so that overall energy intake is not too high. On Tuesday after training, carbohydrate intake is increased as preparation for the match on Wednesday. The meals on Wednesday are high carbohydrate (apart from the breakfast). Thursday is a recovery day and it is about balancing a high carbohydrate intake with a modest energy intake (no training this day). On Friday, training is resumed but energy intake is still modest and carbohydrate intake is modest too (in the 5-6 g/kg per day range). On Saturday, the same pre-match routine is followed, with a relatively high carbohydrate intake several hours before the match. Match day certainly needs to have a similar routine.

Figure 6: Nutrition periodisation for a week in football



Source: prepared by the author.

Example with two matches per week. Green is low energy meals, with a focus on health. Yellow is a modest carbohydrate intake and a focus on protein. Red is a focus on carbohydrate with a good amount of protein.

If only one match is played per week, planning becomes a little easier and it is easier to build up to a match because recovery and preparation will be separated a little more. It is important to keep an eye on overall energy needs. A mistake that is often made is that recommendations for acute recovery are followed but the bigger picture is missed. Players are overfed with carbohydrate.

References

Achten, J., Halson, S. L., Moseley, L., Rayson, M. P., Casey, A., & Jeukendrup, A. E. (April, 2004). Higher dietary carbohydrate content during intensified running training results in better maintenance of performance and mood state. *Journal of Applied Physiology (1985), 96*(4), 1331-40.

Anderson, L., Naughton, R. J., Close, G. L., Di Michele, R., Morgans, R., Drust, B., & Morton, J. P. (December, 2017). Daily Distribution of Macronutrient Intakes of Professional Soccer Players From the English Premier League. *International Journal of Sport Nutrition and Exercise Metabolism, 27*(6), 491-498. doi:10.1123/ijsnem.2016-0265

Bartlett, J. D., Hawley, J. A., & Morton, J. P. (2015). Carbohydrate availability and exercise training adaptation: too much of a good thing? *European Journal of Sport Science, 15*(1), 3-12. doi:10.1080/17461391.2014.920926

Bartlett, J. D., Hwa Joo, C., Jeong, T. S., Louhelainen, J., Cochran, A. J., Gibala, M. J., Gregson, W., Close, G. L., Drust, B., & Morton, J. P. (2012). Matched work high-intensity interval and continuous running induce similar increases in PGC-1alpha mRNA, AMPK, p38, and p53 phosphorylation in human skeletal muscle. *Journal of Applied Physiology (1985), 112*(7), 1135-1143. doi:10.1152/japplphysiol.01040.2011

Brukner, P. (July, 2013). Challenging beliefs in sports nutrition: are two 'core principles' proving to be myths ripe for busting? *British Journal of Sports Medicine, 47*(11), 663-664. doi:10.1136/bjsports-2013-092440

Burke, L. (February, 2004). ACSM and MSSE: nutrition and metabolism perspective. *Medicine & Science in Sports & Exercise, 36*(2), 179. doi:10.1249/01.MSS.0000113469.60836.BA

Burke, L. M. & Hawley, J. A. (November, 2018). Swifter, higher, stronger: What's on the menu? *Science, 362*(6416), 781-787. doi:10.1126/science.aau2093

Burke, L. M., Hawley, J. A., Jeukendrup, A., Morton, J. P., Stellingwerff, T., & Maughan, R. J. (September, 2018). Toward a Common Understanding of Diet-Exercise Strategies to Manipulate Fuel Availability for Training and Competition Preparation in Endurance Sport. *International Journal of Sport Nutrition and Exercise Metabolism, 28*(5), 451-463. doi:10.1123/ijsnem.2018-0289

Burke, L. M., Hawley, J. A., Wong, S. H., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences, 29*(Suppl 1), S17-27. doi:10.1080/02640414.2011.585473

Burke, L. M., Kiens, B., & Ivy, J. L. (January, 2004). Carbohydrates and fat for training and recovery. *Journal of Sports Sciences, 22*(1), 15-30.

Cochran, A. J., Little, J. P., Tarnopolsky, M. A., & Gibala, M. J. (March, 2010). Carbohydrate feeding during recovery alters the skeletal muscle metabolic response to repeated sessions of high-intensity interval

exercise in humans. *Journal of Applied Physiology (1985), 108*(3), 628-636. doi:10.1152/japplphysiol.00659.2009

Coffey, V. G. & Hawley, J. A. (2007). The molecular bases of training adaptation. *Sports Medicine, 37*(9), 737-763.

Coffey, V. G. & Hawley, J. A. (May, 2017). Concurrent exercise training: do opposites distract? *The Journal of Physiology, 595*(9), 2883-2896. doi:10.1113/JP272270

Cox, G. R., Clark, S. A., Cox, A. J., Halson, S. L., Hargreaves, M., Hawley, J. A., Jeacocke, N., Snow, R. J., Yeo, W. K., & Burke, L. M. (July, 2010). Daily training with high carbohydrate availability increases exogenous carbohydrate oxidation during endurance cycling. *Journal of Applied Physiology, 109*(1), 126-134. doi:japplphysiol.00950.2009 [pii] 10.1152/japplphysiol.00950.2009

De Bock, K., Derave, W., Eijnde, B. O., Hesselink, M. K., Koninckx, E., Rose, A. J., Schrauwen, P., Bonen, A., Richter, E. A., & Hespel, P. (April, 2008). Effect of training in the fasted state on metabolic responses during exercise with carbohydrate intake. *Journal of Applied Physiology (1985), 104*(4), 1045-1055. doi:10.1152/japplphysiol.01195.2007

De Bock, K., Richter, E. A., Russell, A. P., Eijnde, B. O., Derave, W., Ramaekers, M., Koninckx, E., Léger, B., Verhaeghe, J., & Hespel, P. (April, 2005). Exercise in the fasted state facilitates fibre type-specific intramyocellular lipid breakdown and stimulates glycogen resynthesis in humans. *The Journal of Physiology, 564*(Pt 2), 649-660. doi:10.1113/jphysiol.2005.083170

Fyfe, J. J., Bishop, D. J., & Stepto, N. K. (June, 2014). Interference between concurrent resistance and endurance exercise: molecular bases and the role of individual training variables. *Sports Medicine, 44*(6), 743-762. doi:10.1007/s40279-014-0162-1

Garcia-Roves, P. M., Garcia-Zapico, P., Patterson, A. M., & Iglesias-Gutierrez, E. (July, 2014). Nutrient intake and food habits of soccer players: analyzing the correlates of eating practice. *Nutrients, 6*(7), 2697-2717. doi:10.3390/nu6072697

Halson, S. L., Bridge, M. W., Meeusen, R., Busschaert, B., Gleeson, M., Jones, D. A., & Jeukendrup, A. E. (September 2002). Time course of performance changes and fatigue markers during intensified training in trained cyclists. *Journal of Applied Physiology, 93*(3), 947-956.

Halson, S. L., Lancaster, G. I., Achten, J., Gleeson, M., & Jeukendrup, A. E. (October, 2004). Effects of carbohydrate supplementation on performance and carbohydrate oxidation after intensified cycling training. *Journal of Applied Physiology, 97*(4), 1245-1253.

Halson, S. L., Lancaster, G. I., Jeukendrup, A. E., & Gleeson, M. (May, 2003). Immunological responses to overreaching in cyclists. *Medicine & Science in Sports & Exercise, 35*(5), 854-861. doi:10.1249/01.MSS.0000064964.80040.E9

Hansen, A. K., Fischer, C. P., Plomgaard, P., Andersen, J. L., Saltin, B., & Pedersen, B. K. (January, 2005). Skeletal muscle adaptation: training

twice every second day vs. training once daily. *Journal of Applied Physiology (1985), 98*(1), 93-99. doi:10.1152/japplphysiol.00163.2004
Hawley, J. A., Burke, L. M., Phillips, S. M., & Spriet, L. L. (March, 2011). Nutritional modulation of training-induced skeletal muscle adaptations. *Journal of Applied Physiology (1985), 110*(3), 834-845. doi:10.1152/japplphysiol.00949.2010
Hawley, J. A., & Leckey, J. J. (November, 2015). Carbohydrate Dependence During Prolonged, Intense Endurance Exercise. *Sports Medicine, 45*(Suppl 1), S5-12. doi:10.1007/s40279-015-0400-1
Hawley, J. A., Lundby, C., Cotter, J. D., & Burke, L. M. (May, 2018). Maximizing Cellular Adaptation to Endurance Exercise in Skeletal Muscle. *Cell Metabolism, 27*(5), 962-976. doi:10.1016/j.cmet.2018.04.014
Hulston, C. J., Venables, M. C., Mann, C. H., Martin, C., Philp, A., Baar, K., & Jeukendrup, A. E. (November, 2010). Training with Low Muscle Glycogen Enhances Fat Metabolism in Well-Trained Cyclists. *Medicine & Science in Sports & Exercise. 42*(11), 2046-2055. doi:10.1249/MSS.0b013e3181dd5070
Impey, S. G., Hearris, M. A., Hammond, K. M., Bartlett, J. D., Louis, J., Close, G. L., & Morton, J. P. (May, 2018). Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis. *Sports Medicine, 48*(5), 1031-1048. doi:10.1007/s40279-018-0867-7
Jeukendrup, A., Hesselink, M. K. C., Snyder, A. C., Kuipers, H., & Keizer, H. A. (October, 1992). Physiological changes in male competitive cyclists after two weeks of intensified training. *International Journal of Sports Medicine, 13*(7), 534-541.
Jeukendrup, A. E. (March, 2017a). Periodized Nutrition for Athletes. *Sports Medicine, 47*(Suppl 1), 51-63. doi:10.1007/s40279-017-0694-2
Jeukendrup, A. E. (March, 2017b). Training the Gut for Athletes. *Sports Medicine, 47*(Suppl 1), 101-110. doi:10.1007/s40279-017-0690-6
Lancaster, G. I., Jentjens, R. L., Moseley, L., Jeukendrup, A. E., & Gleeson, M. (December, 2003). Effect of pre-exercise carbohydrate ingestion on plasma cytokine, stress hormone, and neutrophil degranulation responses to continuous, high-intensity exercise. *International Journal of Sport Nutrition and Exercise Metabolism, 13*(4), 436-453.
McBride, A., Ghilagaber, S., Nikolaev, A., & Hardie, D. G. (January, 2009). The glycogen-binding domain on the AMPK beta subunit allows the kinase to act as a glycogen sensor. *Cell Metabolism, 9*(1), 23-34. doi:10.1016/j.cmet.2008.11.008
McBride, A. & Hardie, D. G. (May, 2009). AMP-activated protein kinase--a sensor of glycogen as well as AMP and ATP? *Acta physiologica (Oxford), 196*(1), 99-113. doi:10.1111/j.1748-1716.2009.01975.x
Morton, J. P., Croft, L., Bartlett, J. D., Maclaren, D. P., Reilly, T., Evans, L., McArdle, A., & Drust, B. (May, 2009). Reduced carbohydrate availability does not modulate training-induced heat shock protein adaptations but does upregulate oxidative enzyme activity in human skeletal muscle. *Journal of Applied Physiology (1985), 106*(5), 1513-1521. doi:10.1152/japplphysiol.00003.2009

Mujika, I., Halson, S., Burke, L. M., Balague, G., & Farrow, D. (May, 2018). An Integrated, Multifactorial Approach to Periodization for Optimal Performance in Individual and Team Sports. *International Journal of Sports Physiology and Performance, 13*(5), 538-561. doi:10.1123/ijspp.2018-0093

Mujika, I., Stellingwerff, T., & Tipton, K. (August, 2014). Nutrition and training adaptations in aquatic sports. *International Journal of Sport Nutrition and Exercise Metabolism, 24*(4), 414-424. doi:10.1123/ijsnem.2014-0033

Nilsson, L. H. & Hultman, E. (December, 1973). Liver glycogen in man; the effects of total starvation or a carbohydrate-poor diet followed by carbohydrate feeding. *Scandinavian Journal of Clinical and Laboratory Investigation, 32*(4), 325-330.

Noakes, T., Volek, J. S., & Phinney, S. D. (July, 2014). Low-carbohydrate diets for athletes: what evidence? *British Journal of Sports Medicine, 48*(14), 1077-1078. doi:10.1136/bjsports-2014-093824

Perez-Schindler, J., Hamilton, D. L., Moore, D. R., Baar, K., & Philp, A. (2015). Nutritional strategies to support concurrent training. *European Journal of Sport Science, 15*(1), 41-52. doi:10.1080/17461391.2014.950345

Philp, A., MacKenzie, M. G., Belew, M. Y., Towler, M. C., Corstorphine, A., Papalamprou, A., Hardie, D. G., & Baar, K. (October, 2013). Glycogen content regulates peroxisome proliferator activated receptor- partial differential (PPAR- partial differential) activity in rat skeletal muscle. *PLoS One, 8*(10), doi:10.1371/journal.pone.0077200

Pilegaard, H., Keller, C., Steensberg, A., Helge, J. W., Pedersen, B. K., Saltin, B., & Neufer, P. D. (May, 2002). Influence of pre-exercise muscle glycogen content on exercise-induced transcriptional regulation of metabolic genes. *The Journal of Physiology, 541*(Pt 1), 261-271.

Pilegaard, H., Ordway, G. A., Saltin, B., & Neufer, P. D. (October, 2000). Transcriptional regulation of gene expression in human skeletal muscle during recovery from exercise. *American Journal of Physiology-Endocrinology and Metabolism, 279*(4), E806-814.

Sanders, M. J., Ali, Z. S., Hegarty, B. D., Heath, R., Snowden, M. A., & Carling, D. (November, 2007). Defining the mechanism of activation of AMP-activated protein kinase by the small molecule A-769662, a member of the thienopyridone family. *Journal of Biological Chemistry, 282*(45), 32539-32548. doi:10.1074/jbc.M706543200

Shamim, B., Devlin, B. L., Timmins, R. G., Tofari, P., Lee Dow, C., Coffey, V. G., Hawley, J. A., & Camera, D. M. (December, 2018). Adaptations to Concurrent Training in Combination with High Protein Availability: A Comparative Trial in Healthy, Recreationally Active Men. *Sports Medicine, 48*(12), 2869-2883. doi:10.1007/s40279-018-0999-9

Simonsen, J. C., Sherman, W. M., Lamb, D. R., Dernbach, A. R., Doyle, J. A., & Strauss, R. (April, 1991). Dietary carbohydrate, muscle glycogen, and power output during rowing training. *Journal of Applied Physiology, 70*(4), 1500-1505.

Stellingwerff, T., Boit, M. K., Res, P. T., & International Association of Athletics Federations (2007). Nutritional strategies to optimize training and racing in middle-distance athletes. *Journal of Sports Sciences, 25*(Suppl 1), S17-28. doi:10.1080/02640410701607213

Svendsen, I. S., Killer, S. C., Carter, J. M., Randell, R. K., Jeukendrup, A. E., & Gleeson, M. (May, 2016). Impact of intensified training and carbohydrate supplementation on immunity and markers of overreaching in highly trained cyclists. *European Journal of Applied Physiology, 116*(5), 867-877. doi:10.1007/s00421-016-3340-z

Van Proeyen, K., De Bock, K., & Hespel, P. (July, 2011). Training in the fasted state facilitates re-activation of eEF2 activity during recovery from endurance exercise. *European Journal of Applied Physiology, 111*(7), 1297-1305. doi:10.1007/s00421-010-1753-7

Van Proeyen, K., Szlufcik, K., Nielens, H., Ramaekers, M., & Hespel, P. (January, 2011). Beneficial metabolic adaptations due to endurance exercise training in the fasted state. *Journal of Applied Physiology (1985), 110*(1), 236-245. doi:10.1152/japplphysiol.00907.2010

Volek, J. S., Noakes, T., & Phinney, S. D. (2015). Rethinking fat as a fuel for endurance exercise. *European Journal of Sport Science, 15*(1), 13-20. doi:10.1080/17461391.2014.959564

Wojtaszewski, J. F., Nielsen, J. N., Jorgensen, S. B., Frosig, C., Birk, J. B., & Richter, E. A. (2003). Transgenic models--a scientific tool to understand exercise-induced metabolism: the regulatory role of AMPK (5'-AMP-activated protein kinase) in glucose transport and glycogen synthase activity in skeletal muscle. *Biochemical Society Transactions, 31*(Pt 6), 1290-1294. doi:10.1042/

Yeo, W. K., McGee, S. L., Carey, A. L., Paton, C. D., Garnham, A. P., Hargreaves, M., & Hawley, J. A. (February, 2010). Acute signalling responses to intense endurance training commenced with low or normal muscle glycogen. *Experimental Physiology, 95*(2), 351-358. doi:10.1113/expphysiol.2009.049353

Yeo, W. K., Paton, C. D., Garnham, A. P., Burke, L. M., Carey, A. L., & Hawley, J. A. (November, 2008). Skeletal muscle adaptation and performance responses to once a day versus twice every second day endurance training regimens. *Journal of Applied Physiology (1985), 105*(5), 1462-1470. doi:10.1152/japplphysiol.90882.2008