PERIODIZED NUTRITION IN MIDDLE DISTANCE RUNNING AND PHYSICAL PREPARATION

A SCIENCE TO PRACTICE CASE STUDY

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INTRODUCTION

A foundational concept within Athletics is "periodization", which from a training perspective is defined as "the purposeful planning and sequencing of different training units (long, medium & short-term training cycles and sessions) so that athletes can attain the desired physiological, [*and psychological*], readiness for optimal targeted performances on demand[1]". A theoretical approach to nutrition periodization was first put forth in 2007[2], and the concept has since been elaborated upon within several reviews[3-10]. Most recently, and as part of the 2019 International Association of Athletics Federations (IAAF) Nutrition Consensus[11], an entire framework on nutrition periodization highlighted the 'reverse engineering' required to successfully implement periodized nutrition interventions[12]. This includes: 1) an appreciation of the sport/event specific performance determinants (including training/competition phase, travel/environmental demands etc); 2) the individual athlete's measured gaps against these performance determinates; and 3) when and where nutrition interventions, coupled with training prescription, can be implemented to address these performance gaps in relation to the sport/event determinants of success. However, despite many published theoretical reviews/frameworks[3-10], there are only a few published case-study examples of periodized nutrition in action[13-17]. Therefore, the goal of this review article is to introduce a hypothetical, but 'real-world', scenario of an emerging elite female 1500m runner on the 2019 IAAF competition circuit. By doing this, we hope to demonstrate the types of novel practical and periodized nutrition interventions a practitioner in the field might consider.

Background: Presentation of the athlete and initial assessment

An emerging elite 19-year old Qatari female middle-distance runner (1,500m specialist) started her competitive-season with a 4:04.35 1500m personal-best that automatically qualified her for the IAAF World Championships (Doha, Qatar; Sept. 28-Oct. 6; projected weather: 30-40°C). After this meet, this Muslim athlete went into a modified 1-month training block during Ramadan. Unfortunately, at the end of this block she suffered an Achilles tendon injury, which required ~3 to 4 weeks of exercise rehabilitation. She has had a history of bone/tendon injuries (3 career stress fractures),

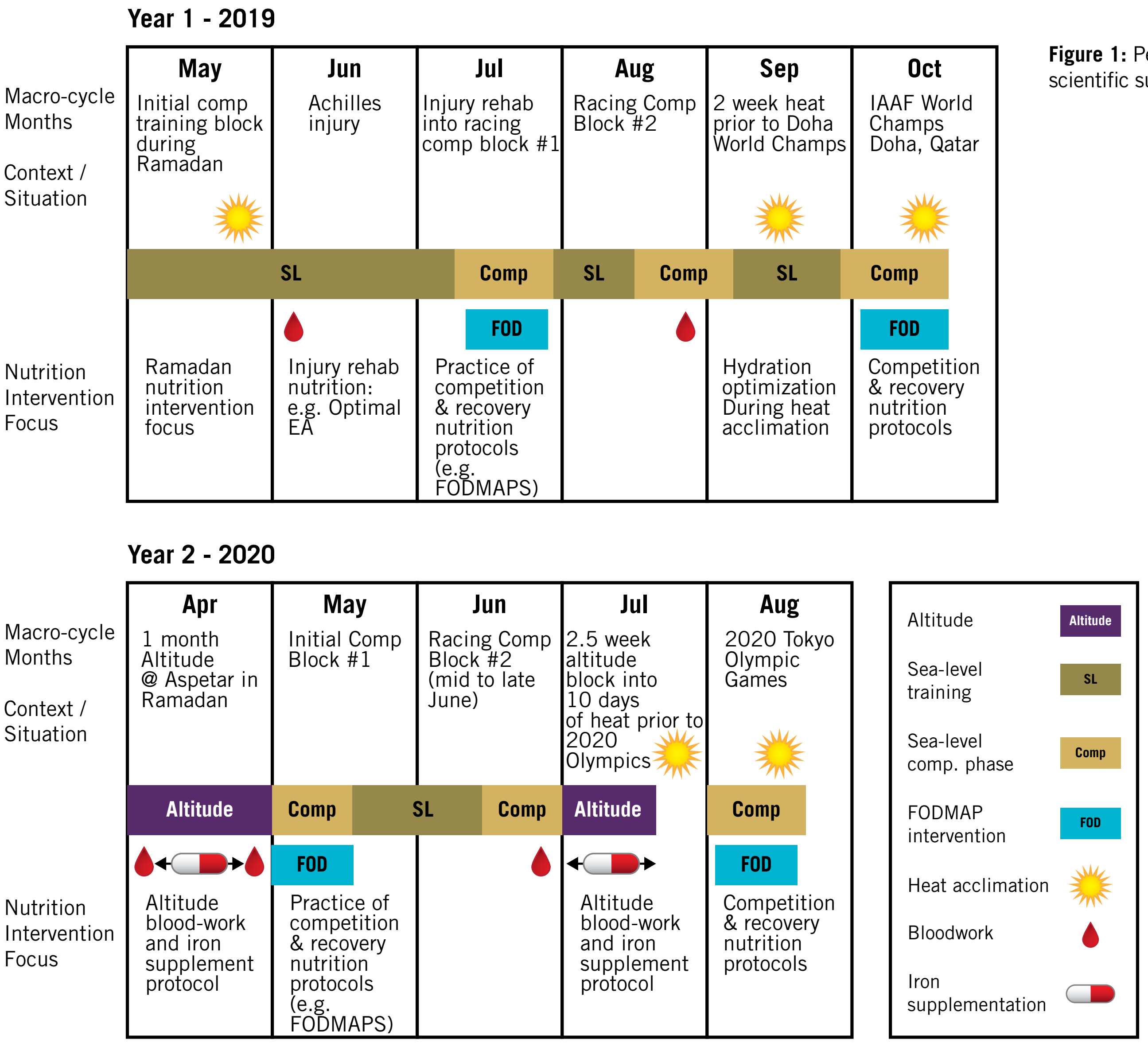

Figure 1: Periodised scientific support plan.

with a dual energy x-ray absorptiometry (DXA) measured bone mineral density (BMD) -2.1 Z-score and oligomenorrhea. After the successful injury rehab, for the rest of the 2019 season the coaching team decided to compete in 2 major racing blocks (5 races per block; July 5-20 and August 16-29) as well as train for 10 days in the heat, prior to the 2019 IAAF World Championships (see timeline in Figure 1). Finally, pre- and post-race nutrition interventions for this athlete have historically been poorly followed; as she tended to have significant gastro-intestinal (GI) issues and does not implement post-race recovery nutrition. This was concerning, sincethe world-championships feature 3 rounds of racing (heats, semi-finals and finals on different days), and thus recovery is of high importance. Historically, the athlete and her coach, who has 20+ years' experience, have had very limited support, and thus limited experiences in travel, altitude, heat and all performance nutrition interventions. However, after receiving increased funding, they were willing and engaged to undertake a series of novel interventions for the 2019 and 2020 season, including engaging in altitude training for the first time, as well as heat acclimatization, leading into the 2020 Tokyo Olympics (projected weather: 30-40°C).

INTERVENTIONS AND METHODS

Ramadan and the Modified Training Phase

Ramadan has unique sports nutrition challenges for Muslim athletes that require training modifications to maintain performance while fasting throughout daylight hours for ~1 month[18]. For this athlete, some of the unique challenges, that could be addressed through nutrition interventions, included: a) minimising loss of body weight (up to 3kg) and muscle mass; b) excessive fatigue during week one of Ramadan; c) reducing complaints of bloating after breaking the fast (Iftar), that affected the quality of training; e) minimising the negative impact of changes to sleep wake cycle on physical performance by controlling the environment; and f) avoiding detraining.

It was agreed that staying in Qatar for Ramadan in both 2019 and 2020 would reduce both physiological and psychological stress of travelling to non-Muslim countries less familiar with Ramadan practices. Simultaneously, she would reap the benefit of sensible fasting hours of fasting in Qatar (~14h) when compared to other countries

Table 1

Meal	*Previous Fasting History*	*Suggested New Routine*
Meal #1 (Iftar) *Time 18:16*	*Water 3 or 5 Large Dates + Laban*	*As previous + sports bar or milk based recovery drink*
	Training from 18:30 to 20:00	
Post Session Recovery *Time 20:00*	*Nil*	*Milk based RTD* recovery drink (50g Carbohydrate 20g Protein) + 1 cup of light popcorn*
Meal #2 *Time 21:00*	*200g Pasta* *100g Chicken in tomato-based sauce*	*1 Chicken shawarma* *1 Pot of Greek yogurt*
Meal #3 *Time 22:00*	*Nil*	*Chicken + noodle broth* *Fruit salad + 2 large spoons Greek yogurt*
Meal #4 (Suhoor) *Time 03:00*	*Chicken sandwich + juice*	*As previous choices + laban or low fat milk* *Protein drink in the night on waking (optional)*

**Ready To Drink (RTD)*

Table 1: Nutrition Intervention During Ramadan.

of the world during this time of the year (e.g. United Kingdom, 17.5h). Training advice was as pragmatic as possible. For example, much of elite middle-distance training features sprinting, sprint drills and explosive movements in the weight room[5,7], and as skill execution and reaction time have been reported to deteriorate across the day[19], sessions requiring psychomotor or reactive capability where completed in the morning. Training ssessions were advised to be short and focused on quality either after breaking the Iftar fast or later in the evening. Key injury prevention strategies focused on monitoring cumulative weekly load and daily wellbeing.

1. Maintaining energy availability (EA) was the primary goal of nutrition interventions during Ramadan to support health, training adaptation and muscle mass[22]. Although training volume was modified, the athlete already had a history of self-imposed carbohydrate and caloric restrictions. Protein intake was estimated at less than 1.6g/kg/day that is shown as less than optimal to maintain lean mass where energy intakes are restricted[20]. As such, several interventions were recommended to a) reduce body weight and lean muscle mass losses and b) maintain training performance (Table 1). These included 1) spreading food volume out more evenly leading up to and including the meal before sunrise (the suhoor meal) to reduce the "bloated" feeling; 2) using different time points as triggers to ingest a protein and carbohydrate recovery drink to increase calories, EA and protein intake. These included the Iftar meal, immediately post training and leaving a protein drink on the toilet cistern in case the athlete awoke to go to toilet before sunrise.

The Injury Phase

Unfortunately, at the end of Ramadan, this athlete suffered an Achilles injury (Figure 1). Although rehab management focused primarily on managing the tendon injury, there was also an investigation into the potential causes of her previous series of injuries (stress fractures), which could have been precipitated by: a) low bone density; b) oligomenorrhea; and finally c) low energy intakes regardless of her training intensity or volume. Taken together, this suggested that chronic low energy availability (LEA) was a primary factor in her injuries. At this stage, the athlete did not demonstrate overt disordered eating, but this is not always required for LEA[21]. To start, routine screening with a sports physician confirmed this athlete was a medium risk of either Relative Energy Deficiency in Sport (RED-S)[22] that put her at a 2-4 times higher risk of sustaining a bone injury[23].

Her management in this phase featured a multi-faceted collaborative team guided by several key principles related to RED-S and nutrition support for an injured athlete:

1. The immediate priority was to establish adequate EA for her rehabilitation. Contemporary guidelines were emphasized using professional sports nutrition counselling. These included addressing the quantity of energy consumed, but also food choices to perfect macronutrient availability for reduced workloads during this injury phase[24].
2. Given the importance of vitamin C and collagen peptides in rebuilding injured tendon strength[25,26] a collagen peptide supplement (10g hydrolyzed collagen, 200mg vitamin C) was introduced daily 1 hour before and immediately after contemporary recommendations of progressive tendon loading.
3. Avoidance of LEA to stay injury and illness free would increase the likelihood of this athlete achieving her performance goals[27]. To achieve this, free time during this period was used to engage both the athlete and her coach in a re-education program related to

better nutritional practices. Specifically post training nutrition, pre-planned fluctuations of carbohydrate intake on higher volume or high intensity sessions and maintaining a consistent level of protein intake, preferably using dairy-based products for increased calcium. It was hoped that this would a) keep energy above 30Kcal per kg Fat Free Mass (Kcal/KgFFM) that has been shown to stop disruption of bone formation[28] and b) improve support team knowledge which was considered a contributing factor to inadequate nutrition following her training sessions.

4. Finally, supplementation strategies for improved bone and tendon health were discussed. Recent blood tests showed a lower level of vitamin D 50 nmol/L) which some studies have indicated may limit muscle recovery and in some cases is linked to poor bone health[29]. Although blood calcium was normal, a pre-exercise meal or supplement has been shown to limit disturbances in bone reabsorption in periods that include multiple sessions per day[30]. On that basis the athlete was recommended a low dose vitamin D supplement (2000-4000 IU/day) in the winter months and a 1000mg calcium pre-exercise supplement prior to her first session on days with multiple sessions, followed by milk-based recovery drink. Continued use of the collagen supplement after the anticipated 4-week return to performance was encouraged to offer further benefits of reduced tendon pain[31].

Preparation camps using special environments

Over the 2019 and 2020 seasons this athlete was exposed to very hot training and competition environments (e.g. 2019 Doha World Champs). Using increased funding, she and her coach agreed to implement two altitude training camps in 2020 in attempts to further optimize race performance outcomes (Figure 1). There were many important nutrition and hydration interventions to consider to optimize training and competition adaptation and outcomes in hot weather and hypoxic conditions. Furthermore, recent emerging evidence suggests that the concurrent environmental implementation of heat and hypoxia may be counterproductive[32,33] to optimize heat-based adaptations and performance. Accordingly, all heat/altitude camps were sequentially ordered

Nutrition & Hydration Considerations for Heat Adaptation Camps

It is now well established that the key mitigating factor to combat heat related performance decrements, and/or heat related illness, is implementing a prolonged heat adaptation period. A recent consensus statement clearly identified that heat acclimation or acclimatization (HA) over 5 to 14 days can significantly improve endurance-based performance in the heat[34]. Optimal HA protocols tend to implement controlled (either heart rate, ratings of perceived exertion and/or core temperature) training in the heat for >60min/day over 5 to 14 days for full acclimation, which has been recommended to this athlete prior to each of her major global championships (Figure 1). However, despite considerable recent research on HA, there remains limited knowledge on aspects of periodization and associated decay rates[35,36].

From a hydration perspective, several research groups have hypothesized that acutely restricting fluid intake during heat protocols, causing permissive dehydration of ~1 to 3% body weight, may further augment physiological strain and fluid regulatory hormonal responses resulting in even greater positive heat adaptations compared to euhydration protocols[37-39]. However, a large recent study demonstrated no effect of hydration status (training and recovery while euhydrated vs. slightly dehydrated (~2%BW)) on various markers of HA (e.g. PV, core temp) or time-trial performance when sub-elite athletes were matched across the groups while training in the heat via internal load over a 5-day HA protocol[40]. Accordingly, at this point, we recommended that due to the deleterious performance and heat effects of profound dehydration this athlete aspired to remain well-hydrated throughout her heat adaptation training camps. This was primarily monitored via morning urine specific gravity checks, along with morning body weight measurements.

Albumin, the most abundant blood protein, has been shown to have significant protein synthesis post exercise with the supplementation of dietary protein in a dose-response manner[41]. Furthermore, in a 5-day HA study, there was significantly greater albumin (~+9%) and plasma volume expansion (~+8%) when subjects were immediately supplemented with protein and carbohydrate post HA training compared to the same amount of fluids with no nutrition[42]. So, accordingly, and in agreement with contemporary recovery sports nutrition guidelines, this athlete and her coach were always instructed to consume an adequate recovery snack/ beverage post heat training.

Nutrition and Supplement Considerations for Altitude Training Camps

Altitude can provide an alternative stimulus for adaptation; however, as with training, the stress of altitude had to be strategic and mitigated by optimal nutrition interventions to ensure peak adaptation. Contrary to popular belief, there is no scientific evidence that working at typical altitudes commonly used at altitude training camps for athletes (~1600 to 2400m) requires additional dietary protein or carbohydrate beyond what is required during hard training at sea-level[43]. Consequently, this athlete was advised to continue with daily carbohydrate and protein intakes that were reflective of this training block, which was higher in volume irrespective of altitude.

What is well established is that altitude training not only provides a stimulus to potentially increase red blood cells (RBC) by ~3 to 5% over 3 weeks (measured in studies as hemoglobin mass (HBmass)[44,45], but it can also positively impact non-hematological factors, such as muscle buffering and mitochondrial biogenesis[46]. Currently, the vast majority of knowledge on the physiological effects of altitude training relate primarily to aspects of HBmass/RBC production with a series of studies having established that the optimal hypoxic dose is approximately 3 to 4 weeks at altitudes of ~2000 to 2500m[47,48]. If these hypoxic doses are satisfied, athletes can expect, on average, an approximate 1% increase in HBmass for every 100hrs at altitude[46]. However, altitude RBC responses are highly individual[49], with some athletes showing 10% increases in HBmass and others showing no increases over the same altitude training camp.

One of the largest controllable factors in optimizing HBmass at altitude is optimal iron bioavailability[50,51]. This was a key consideration in the case of this athlete who 5 weeks prior to the first camp in

2019 presented with lower serum iron levels (ferritin of 15 ng/mL, with normal, but lower, hemoglobin of 12.2 g/dL), which is not uncommon where LEA is indicated[52-54]. Novel data suggests that iron supplementation before and during altitude is possibly more important for HBmass than incoming iron stores (ferritin), as long as hemoglobin is within normal ranges[55,56]. This contemporary research shows a near dose-response relationship with increasing iron intake (up to 200mg of elemental iron/day) and subsequent increases in HBmass while training at altitude. In this series of studies, Govus et al[55] and Garvican-Lewis et al[56] examined 178 athletes who participated in altitude camps and found that those athletes who did not supplement with iron had minimal HBmass increases of only +1.2% (within HBmass measurement error), athletes that supplemented with 105mg of elemental iron per day increased HBmass by +3.3% and those that supplemented with 210mg of elemental iron per day increased HBmass by +4.0%. Clinically elevated endogenous iron stores can have negative health outcomes[57,58]. To avoid a possible risk from excessive iron supplementation, we recommended further involvement of a sports medicine physician in the prescription of supplementation. Several other potential altitude-based nutritional interventions have been indicated in recent reviews[51,59], however in the case of this athlete it was decided to keep things simple to ensure adequate EA, training recovery, iron supplementation and optimal hydration on a daily basis.

TABLE 2

Race Day Time	*Food*
9:00	*Oats made with **lactose free milk** + banana*
12:00	*Chicken **corn tortillas** + **strawberries***
16:00	***Rice cakes** + mashed banana topped with jam*
19:00 (warm up)	*Fluids ad libitum*
20:00 Race	
20:30 (post race)	*Carbohydrate and protein shake + 1 cup of light microwave popcorn* *Gel (optional if delayed return for doping test)*
22:00	***Rice** + meat-based meal + pre-bed glass light milk*

Table 2: Summary of race strategy with Low FODMAP swaps (bold).

**Travel food kit; tortillas, microwave popcorn, rice cakes*

Pre-competition phase

A key concern with this athlete was her avoidance of carbohydrate as a coping mechanism to reduce gastrointestinal (GI) disturbances prior to, during and after competing. Prior interventions had increased her confidence to increase carbohydrate in higher intensity training periods. However, any middle-distance athlete avoiding carbohydrate in competition would have less than optimal glycogen stores and limit their performance[60]. This phase used opportunities at training camps in special environments to try interventions that would hopefully a) improve delivery of carbohydrate to working muscles; and b) improve physical tolerance to daily carbohydrate at levels required to sustain performance over 3 heats. These were guided by several scientific principles, albeit observed in longer distance athletes namely that:

1. The intestine can adapt to changes in diet and then absorb nutrients at different rates[61].
2. The gut can be trained in a relatively short period of time to improve gastric emptying and absorption. For this athlete, it was hoped that using consistently targeted levels of exogenous carbohydrate circa 6-8g.kg.BM.day (as opposed to <5g.kg.BM.day previously found) would provide a "quick win" through improving carbohydrate transport and reduce complaints of bloating and discomfort[62].
3. Mental (e.g. anxiety, nerves) and environmental (e.g. heat) factors were important race day considerations for optimal GI function. Different aspects of a pre-planned strategy were practiced in training and events in the lead up to Doha 2019 World Championships. This included the integration of higher concentrated carbohydrate gels and drinks that would be used between heats, and higher levels of exogenous carbohydrate generally required circa 1-1.5g.Kg.Hr in the hours after the event to optimise muscle glycogen[63].
4. Finally, relief of GI symptoms can be associated with avoidance of gluten containing foods. Reducing FODMAP (fermentable oligosaccahrides, disaccharides, monosaccharides and polyols) intake is a factor that can improve symptoms and minimise GI disturbance during heats[64,65]. For this athlete, that required several food swap suggestions in the week leading in, and during her major competitions (Table 2).

Competition phase

Several additional interventions were implemented to optimise performance leading up to and during competition, including the addition of performance focused supplementation. Despite many ergogenic aids being commercially available, several important factors required consideration prior to their use. Firstly, very few sports supplements (caffeine, nitrates and buffers) have been found to improve middle distance running performance[66]. Secondly, for this athlete, the benefit (enhanced performance) versus risk (e.g. tested/clean source to minimize risk for an anti-doping rule violation[67] and or possible GI disturbance) was important in the choice and dose of any supplement used. Selection of supplements required careful risk assessment, advice on product procurement using third party tested schemes recognized by various global National anti-doping authorities, and finally documented athlete

Common Situations	Solutions
Sat next to person who is unwell e.g. on a plane or in a lift	• *Request to be moved.* • *Avoid using lifts or being in confined spaces with other people* • *If not possible, wear face mask for flight duration or in these confined spaces (that includes athlete competition briefings)*
Opening doors or holding hand rails e.g. on bus during transport	• *Use hand sanitizers after touching surfaces* • *Do not touch eyes or mouth with hands* • *Use lower / less used parts of door handles where possible*
Mouth getting dry from AC on planes	• *Take drinks bottle and ask to be filled with water on flight.* • *Chew gum*
Using bathrooms	• *Avoid touching toilet seat if possible* • *Shut toilet lid before flushing* • *Always wash hands and use hand sanitizer as additional precaution after using toilet*

Table 3: Simple Travel Hygiene Counter Measures.

education on her own liability under the World Anti-Doping Association (WADA) code when taking a supplement.

In a recent meta-analysis on caffeine, four studies where the duration of running was relevant to middle distance (2-15min) showed a 1% improvement in performance[68]. As a nonhabitual caffeine user, the threat of further gut irritation to this athlete from traditional approaches to caffeine ingestion such as coffee and capsule ingestion where high. Recently, caffeine gum has been demonstrated as an effective alternative method of delivery[69]. Subsequently, in line with contemporary guidelines[70] a lower dose of 3mg of caffeine /kg BW via caffeine gum was recommended during the competition warm up 30 to 60 min prior to competition. This was first trialed around key training sessions, before implementation into lower priority and then finally tin major targeted competitions.

Interventions aimed at reducing perturbations linked to fatigue were discussed. Arguably the strength of evidence in middle distance running is more in favour of intra and extra cellular buffering. However, the potential GI side effects for this athlete ruled out the use of sodium bicarbonate. In contrast, the use of 3-6g/day of beta alanine (BA) over a 2-4-week period can be effective in raising muscle carnosine level which has been proposed to have several physiological functions including acting as an intracellular buffer[71] and has no GI side effects. More recently, chronic intakes of 6g/day have been suggested to result in even higher muscle carnosine levels[72]. Although effect sizes of BA consumption seen in various meta analyses[73,74] are higher in recreational athletes than well trained athletes, it may still have a small but meaningful effect on performance in elites. Consequently, in the absence of any paresthesia side-effects at lower doses, 6g / day was established over a 2 months period prior to the world championships in Doha.

5. Travel and staying in foreign destinations involving more than a 5 hour time difference was going to be an essential part of this athletes year plan. Such a time difference has been shown to increase the incidence of illness two to threefold[75]. Using contemporary guidelines[76], selected pragmatic advice on travel hygiene relevant to this athlete was provided (Table 3). This was part of a wider strategy to 1) minimise the deleterious effects of travel on athletic performance 2) maintain BW in training tapered periods; and 3) reduce psychological stress associated with living in shared athlete accommodation prior to a major game which can affect performance[77].

CONCLUSION

In modern day elite level track and field athletics, athletes and their coaches face an ever increasing "toolbox" of novel sports-science-based interventions that could enhance performance. However, to optimize competition performance, these need to be well planned and considered in the context of the latest evidence, the needs of the individual athlete, and finally the financial and time constraints available. The theoretical case study presented in this article demonstrates how nutrition periodization could help athletes and coaches effectively plan training and other interventions in the physical preparation and lead up to major competitions to optimize performance.

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