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LETTER

Reply from Louise M. Burke

We thank Mr Lindseth for his comments on our recently published paper on the metabolic and performance responses to a low-carbohydrate, high-fat (LCHF) diet in elite athletes (Burke *et al.* 2017). It is always of concern to confront assertions that there may be methodological flaws in your research and since there are a large number of issues raised, we have tried to address these as comprehensively as possible while being aware of the need for brevity.

First, we suggest that sport nutrition be viewed as a rich palette of choices that may enhance a variety of activities or be tailored to specific aspects of the preparation of athletes. Although in 'real life' athletes often employ a large number of individual strategies within their nutrition plans as well as personalising the way they are implemented, the usual scientific method to commence the exploration of a novel concept is to isolate the practice and investigate it in its strongest format. In the introduction to our paper, we outlined that our study was undertaken to investigate a specific ketogenic LCHF diet similar to that previously studied (Phinney *et al.* 1983) and more recently reincarnated in a popular diet book (Volek & Phinney, 2012). Our rationale for undertaking the study covered both the theoretical value of enhancing athletes' capacity to oxidise endogenous fat stores to fuel their training and competition activities (an interest, we and others have pursued in a variety of different ways over many years of study) and the current fervour with which claims are being made for this nutritional strategy. The methodology of the original study and the practice of this diet are explicitly described in these publications, so it is difficult to know how we could have claimed to study the LCHF diet without implementing it according to these directions. Other iterations of macronutrient intake manipulations may prove to offer benefits to athletic performance in future studies, but this was not the intention of the current investigation. Indeed, the alternative dietary prescription proposed by Lindseth as having greater relevance to athletic performance was not clear to us, but we suggest it would take a very brave research group to tackle a study with as many moving parts as he proposes. We can assure readers that the resources and commitment needed to undertake the current study with a rigorous control of diet and training, even with a clearly defined dietary prescription, is not for the faint-hearted. This probably explains why there has only been one previous investigation involving a total of just five subjects of this topical dietary philosophy (Phinney *et al.* 1983). Nevertheless, this lack of research creates a vacuum for sports scientists who are confronted by the claims and questions around its purported benefits.

To be clear, we did not involve a 'run-in' to the intervention with a gradual shift to the LCHF diet because the study (Phinney *et al.* 1983) and the popular eating plan (Volek & Phinney, 2012) explicitly state that the *modus operandi* of the plan is chronic adaptation to a ketogenic state. Thus, full and sustained exposure is recommended to achieve the optimal effects (Volek & Phinney, 2012). Our athletes did, however, undertake a 'run-in' in terms of training, in that they were made aware of the training and testing programme prior to the camp, and accommodated it within their annual training plans. The annual training programme for competitive athletes is composed of a series of mesocycles such as the one undertaken within the study, and our specific programme was assembled with their input as well as provided with a degree of flexibility (six of the weekly sessions were compulsory and monitored, while others were adapted to each athlete's individual level and goals). As a result, each of the groups was subjected to a similar training effect in terms of the prescribed/achieved plan; indeed our finding that each group achieved a similar increase in maximal aerobic capacity across the training intervention provides a high degree of comfort that the stimulus was similar even though there were impairments of perception of effort and training quality of various duration and intensity with individual subjects on the LCHF diet. Lindseth makes an excellent point about the importance of controlling for the belief effect attached to a treatment and our methods section clearly outlines the substantial efforts we made to do this. We canvassed potential subjects around their interest and support for each of the dietary interventions, and the primary characteristic used to allocate athletes to each treatment group was their belief that they would achieve a performance improvement. In the case of the LCHF group, further instructions were provided regarding the short-term impairment of training quality and capacity, and the athletes both anticipated this and believed that it contributed to the expected benefit. Indeed, these endurance athletes frequently undertake specialised strategies such as altitude training in which there is a short-term impairment of training quality in return for enhanced physiological adaptation, so this concept is neither foreign nor negative. An additional feature designed to mitigate a potential nocebo effect was the scheduling of the retesting of maximal aerobic capacity prior to the second 10 km race, providing the LCHF group with positive feedback about gains made during the training block before they raced.

We agree with Lindseth that the effects of this (or any dietary intervention) on athletic performance are likely to be multifactorial and we are currently in the middle of a follow-up study as well as preparing a series of additional papers from our work to investigate the effects on other body systems. Indeed, some of these may have important or longer term relevance to health or performance. However, we feel these should not distract from the clear evidence from the current paper that the muscle's plasticity in being able to retool to achieve substantial increases in fat metabolism has a predictable and negative effect on the economy of exercise, which becomes important at the high exercise intensities that are characteristic of competitive sport. We constructed menus for each of the dietary interventions to represent a nutritionally optimised but practical form of the underlying nutrition principles, and in the case of the LCHF diet we were aided by clear prescriptions of suitable food choices and recipes provided by its originators (Volek & Phinney, 2012). Although we focused on wholesome/unprocessed foods as much as possible, we are cautious with the description that the LCHF diet allows 'substantial amounts of berries, vegetables and nuts'; indeed, there are limits to the quantities of these and many other nutrient-dense foods within

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the LCHF dietary rules, either due to the tight carbohydrate restrictions or due to the additional need to moderate protein intake (Volek & Phinney, 2012). In general, however, we were able to meet the daily recommended intakes for micronutrients on the LCHF diet, but the micronutrient density of the diet was lower than that of the other carbohydrate-based diets (Mirtschin *et al.* in review), despite the real-life inclusion of highly processed sports foods/drinks in carbohydrate-focused plans.

Finally, we believe both the rationale of our current study (to implement the basic principles of each dietary philosophy in their intact format for the pre-event meal in the post-testing performance test) and the rules of the International Association of Athletics Federations governing feedzones during a 10,000 meter track event in race walking (only water may be provided) fully justify the methodology used in the race component of the investigation. However we would also like to correct the apparent misunderstanding of the carbohydrate mouth rinse phenomenon and literature as it is portrayed in Lindseth's letter. This exciting new area of sports nutrition shows robust evidence of immediate effects of the central nervous system (CNS) stimulation of mouth rinsing with carbohydrate on the pacing and performance of high-intensity exercise; this is distinct from the peripheral effects associated with ingesting and achieving a metabolic effect of this nutrient (Burke & Maughan, 2015). It opens up new areas of practice in sports nutrition, including as we have previously suggested, the opportunity to 'rescue' the fatigue or suboptimal performance associated with low carbohydrate availability (Burke & Maughan, 2015). Indeed, our group published the study that showed that these are greater in relative effect when applied to a situation of low carbohydrate availability compared with high carbohydrate availability, although the best performance outcome was achieved by the combination of high carbohydrate availability and carbohydrate mouth rinse (Lane *et al.* 2013). However we point out that these CNS effects appear acutely with the exposure of the oral cavity to carbohydrate (Chambers *et al.* 2009), as would be the case if we had been able to provide carbohydrate during the race, and we are not aware of any evidence or discussion that a single episode of mouth exposure to carbohydrate from the a pre-event meal would have a sustained or latent CNS effect that would be robustly detected after a further 2–3 h without any further exposure to carbohydrate.

In summary, we appreciate the interest of Lindseth and others in our study of the LCHF diet and athletic performance. We hope that this will not be the last study of this dietary philosophy since there are always many new angles or applications to explore. However, we feel that the methodology of the current investigation was justified and revealed some important insights.

Louise M. Burke

Australian Institute of Sport, Canberra, and Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Australia

Email: louise.burke@ausport.gov.au

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