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Prevalence of reducing carbohydrate intake and fasted training in elite endurance athletes and association with bone injury

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Abstract

There are conflicting reports both within the lay media and scientific literature regarding the use and benefit of dietary practices that aim to reduce CHO intake in endurance athletes. This study aimed to determine the prevalence of intentional reduction of CHO intake and fasted training in elite endurance-based athletes using a semi-quantitative questionnaire. Bone is a nutritionally modulated tissue; therefore, this study also aimed to explore if these dietary practices are potentially associated with bone injury incidence. The reported reduction of CHO intake was prevalent (28%) with the primary motivation being maintenance or manipulation of body composition. However, discrepancies in athletes' awareness of CHO intake were identified providing a potential avenue of intervention especially within applied practice. The use of fasted training was more prevalent (38%) with athletes using this practice for both body composition manipulation and promoting a desired adaptive response. Forty-four per cent of participants had suffered a radiographically confirmed bone injury at some point in their career. There was no association between reduction in CHO intake and bone injury incidence; however, the incidence of bone injury was 1.61 times higher in those who currently use fasted training compared to those who have never used it or who have used it in the past. Although a direct causal link between these dietary practices and the incidence of bone injury cannot be drawn, it provides robust justification for future investigations of the potential mechanisms that could explain this finding.

KEYWORDS

bone injury, carbohydrate, endurance

Highlights

- The self-reported use of reductions in CHO intake (28%) and fasted training (38%) is prevalent in elite endurance-based athletes and comparable to previous investigations in

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this area. Controlling body composition and promoting adaptive responses were common rationales for use.

- The incidence of bone injury is also high (44%) and there may be some association between bone injury incidence and fasted training. Further controlled experimental studies are required to determine the direct effect of nutritional strategies commonly adopted by endurance athletes on bone metabolism both acutely and chronically.
- There appears to be a gap in some athlete's knowledge and awareness of CHO rich foods and appropriate consumption of CHO to support endurance training and performance according to current guidelines. Future work should aim to explore and address this area further.

1 | INTRODUCTION

The manipulation of carbohydrate (CHO) intake to support adaptations to endurance capacity is a common consideration for athletes although there remains considerable debate regarding its practicality and efficacy. Key opinion leaders are divided, with some stating consensus for adaptation to a low CHO diet (Noakes et al., 2014; Phinney et al., 1983; Prins et al., 2023; Volek et al., 2015), while others being more in favour of a periodised approach (Impey et al., 2018; Jeukendrup, 2017; Stellingwerff et al., 2019). A periodised approach ensures various components of the athlete's diet, including CHO intake, are closely aligned with the goal or desired training outcome based upon factors including training volume, training intensity, training session objectives and race specific strategies. Within this periodised approach, it is also recognised that there may be some benefit in using dietary practices that lead to a reduction in the CHO availability, since they can lead to upregulation of signalling pathways involved in positive adaptations for the endurance phenotype including mitochondrial biogenesis and increases in fat utilisation and oxidation (Burke et al., 2017, 2021; Hawley & Morton, 2014; Hulston et al., 2010; Phinney et al., 1983). However, the evidence of an associated performance benefit in elite athletes is lacking, with some showing a negative impact on performance and wellness in elite athletes (Burke et al., 2017; Mujika, 2019). With a lack of consensus in the scientific literature, this may result in adoption of various approaches to reducing CHO intake by athletes and coaches. Therefore, it is important to establish reported prevalence and perceived rationale for use in this population.

Bone health and bone injury risk are important considerations when contemplating use of such nutritional strategies, particularly for those athletes that are already at risk of adverse injury and health outcomes (Rizzone et al., 2017; Tenforde et al., 2018). There are several known risk factors that influence bone health and the risk of bone injuries including training load and the mechanical loading characteristics of the activity (Beck & Drysdale, 2021). It is also important to consider that bone tissue is nutritionally modulated (for review see Walsh and Henriksen, 2010), and there are several considerations that are relevant for athletes (as outlined in a recent review by Sale and Elliott-Sale, 2019) including both energy and CHO availability. Endurance training has a high energy demand, and many endurance-based sports are weight categorised or weight sensitive, both of which can increase the risk of low energy availability (LEA) (Logue et al. (2018); Logue, Madigan, Delahunt, et al. (2018). The occurrence of LEA in endurance trained athletes has been associated with stress fracture occurrence, as 46 of 70 (77%) participants who had suffered a stress fracture over a 12-month period were at a risk of LEA (Logue, Madigan, Heinen, et al., 2018; Logue, Madigan, Heinen, et al., 2018). Other work has shown that within a group of athletes who were diagnosed with low bone mineral density (BMD), 90% presented with LEA at some point during a competitive season, with the main driver of LEA deemed to be low energy and CHO intake relative to the energy expenditure because of high training demands. Seventy percent of athletes within the same study also presented with restrictive eating patterns in an attempt to control weight (Viner et al., 2015). Recent evidence suggests that CHO availability may act somewhat independently to EA in terms of modulating the bone metabolic response to exercise (Fensham et al., 2022; Hammond et al., 2019; Sale et al., 2015).

Training with reduced CHO intake should be carefully considered in terms of its potential impact on competition performance, health, well-being and potential injury risk (Bilsborough & Crowe, 2003). Therefore, the primary aim of this study is to determine the reported prevalence of and perceived rationale for the reported use of intentional reduction in CHO intake and fasted training by elite (national, international and world class) endurance-based athletes using a semi-quantitative self-reported questionnaire. A secondary aim of the study is to determine if there is an association between the use of these practices and the incidence of self-reported radiographically confirmed bone injury and conditions that can potentially influence bone health and/or athletic performance.

2 | MATERIALS AND METHODS

2.1 | Participants

Inclusion criteria were male and female athletes aged 18–35 years engaged with training for at least 8 h per week who had competed at the national championship level as a minimum. This project was carried

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out in partnership with an applied sport science service delivery partner, and as such, we recruited from the endurance-based sports that are supported by them which included: athletics, swimming, rowing, triathlon, cycling, pentathlon and boxing. The criteria for inclusion of particular sports was based on the static and dynamic components associated with peak performance within each sport during competition as set out in a classification table by Mitchell et al. (2005). Based on this classification to be included in the study, the sport must have a high dynamic component where the peak intensity during competition is greater then 70% $\dot{V}O_{2max}$. The study was approved by the local research ethics committee (2020_05_15_EHS).

2.2 | Questionnaire design and outline

Participants anonymously completed a semi-quantitative questionnaire using an online survey tool (Qualtrics, Provo), see Appendix 1, investigating: (1) participant demographics, (2) participants ability to identify foods rich in CHO, (3) bone injury history, (4) reported reduction in overall CHO intake over a period of weeks to months in a season and (5) reported use of fasted training.

2.3 | Data and statistical analysis

Data were first screened to exclude ineligible datasets. Any participants who identified fish, eggs, red meat or poultry as CHO rich foods were excluded from all analysis. Bone injury data were screened to ensure that the self-reported injuries met a minimum diagnosis criterion; a bone fracture or bone stress reaction was required to have been diagnosed using a radiographical scan by a qualified healthcare professional and any bone injuries that did not meet this minimum diagnosis criteria were excluded from analyses. Any non-bone injuries (*i.e.*, soft tissue injuries) and where the type is unclear or not specified were also excluded. Several questions had predefined choice responses, but participants were also able to specify an additional response by clicking 'other, please specify'. These additional responses were screened by the researchers and categorised accordingly. The prevalence of reported reductions in CHO intake and fasted training were assessed using the following equation:

$$\text{Prevalence}\,(\%) = \frac{\text{Number of positive response}}{\text{Sample size for the metric of interest}} \times 100$$

Data are presented as mean $\pm$ 1 standard deviation, the number of times a response was chosen (n) and the percentage of the total responses to a given question. Responses were subdivided based on several categories for further analysis including sex: male versus female; sport: athletics versus triathlon versus cycling versus swimming versus rowing versus boxing versus pentathlon and athlete level: National versus International versus World (including World Championships, Olympic and Paralympic). The reduction in overall CHO intake, use of fasted training and bone injury incidence were compared across these subgroups using the chi-square analysis and Cramer's V effect size. The cause of injury was also compared across sport using the chi-square analysis and Cramer's V effect size. Where a significant chi-square association was identified *post-hoc* tests were conducted using adjusted residuals and a Bonferroni correction. Continuous interval data were analysed using *t*-tests. For initial YES/NO questions in each section, the percentage was calculated from the entire sample who had responded to that question. For subsequent questions, the percentage was calculated based upon the n remaining after the initial question. Following the initial question, skip logic was applied so that only relevant questions and answer choices were displayed which were relevant to the participant's initial choice. A negative binomial regression model was used to determine the effect of reported reductions of overall CHO intake and the use of fasted training on bone injury incidence. The effect of biological sex, sport, athlete level, number of years of dedicated training and weekly training volume were also included in the model as they can potentially influence bone injury incidence. It was ensured that the data met Poisson distribution through a Kolmogorov–Smirnov test, and it was decided to use a negative binomial model based on dispersion assumptions, which were tested through goodness of fit statistics. All data and statistical analyses were carried out using Microsoft Excel (Microsoft, Redmond) and SPSS Statistics 27 (IBM).

3 | RESULTS

Eight hundred and twenty-three respondents consented to participate between September 2020 and June 2021. After inclusion, exclusion and minimum completion criteria were applied, 327 responses were included in the final analysis (146 male and 181 female). Participants were aged 24.9 $\pm$ 5.0 years and with 134 responses from athletics, 52 from triathlon, 47 from cycling, 44 from rowing, 32 from swimming, 17 from boxing and 1 from pentathlon. 164 were national championships level athletes, 100 were international level athletes and 63 had competed at a world championships or Olympic Games. Participants had been carrying out dedicated training for 6.7 $\pm$ 4 years, and the average weekly overall weekly training volume was 15.2 $\pm$ 5.0 h.

3.1 | Identifying CHO foods

Participants were able to identify at least one food that was rich in CHO with all participants correctly identifying that grains, for example, pasta, bread, rice and cereal, were CHO rich. Any participants who identified fish, eggs, red meat or poultry as CHO rich were excluded from the study. Twelve percent of participants indicated that dairy, for example, milk, cheese or yoghurt, were CHO rich.

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3.2 | Reported reduction of CHO intake

Ninety-four participants (29%) reported currently intentionally reducing overall CHO intake over a period of weeks to months within the season. Pearson's chi-square test showed a significant association between the athlete level and reported reduction in CHO intake (X^2(2, n = 327) = 10.92, $p = 0.004$ and Cramer's $V = 0.184$), such that those who competed at the international level (39%) were more likely to report it compared to those who competed at the national or world class level. There was also a significant association between sport and reported reduction of CHO intake (X^2(5, n = 326) = 13.54, $p = 0.019$ and Cramer's $V = 0.204$). Those who competed in boxing were more likely (65%) to report reducing CHO intake compared to other endurance-based sports. The single athlete competing in pentathlon was removed from this analysis. Further information regarding reported reductions in CHO intake is depicted in Figure 1 and in supplementary material.

3.2.1 | Training in the fasted state

Training in the fasted state was more prevalent ($n = 126$, 38.4%) than reported reduction of CHO intake. Pearson's chi-square test showed an association between biological sex and the use of fasted training (X^2(1, $N = 327$) = 9.116, $p = 0.003$ and Cramer's $V = 0.167$), such that men (47%) were more likely to use fasted training compared to women (31%). There was also a significant association between sport and the use of fasted training (X^2(5, $N = 326$) = 38.78, $p < 0.001$ and Cramer's $V = 0.345$) such that triathlon had the highest prevalence of the use of fasted training at 64% followed by boxing (59%), cycling (47%), athletics (37%), rowing (14%) and swimming (13%) had the lowest. Further information regarding athlete use of fasted training is depicted in Figure 2 and in supplementary material.

3.2.2 | Bone injury incidence

After appropriate exclusions had been applied, a total of 114 athletes reported an injury, with a total of 198 injuries being reported. Pearson's chi-square test showed significant association between the sport and bone injury incidence (X^2(5, $N = 326$) = 13.279, $p = 0.021$ and Cramer's $V = 0.202$). Boxing had the highest prevalence of bone injury occurrence at 53%, followed by athletics (47%), cycling (45%), rowing (32%), triathlon (27%) and swimming (25%). Pearson chi-square test showed a significant association between sport and injuries that were caused by overuse or overload (X^2(5, $N = 326$) = 31.626, $p < 0.001$ and Cramer's $V = 0.311$). The proportion of overuse/overload bone injuries reported in athletics was significantly greater than the expected count. Pearson's chi-square test also showed a significant association between sport and injuries that were caused by impact (X^2(5, $N = 326$) = 36.635, $p < 0.001$ and Cramer's $V = 0.316$). The proportion of impact injuries reported in cycling was significantly greater than the expected count. The single athlete competing in pentathlon was removed from this analysis. Further information regarding athlete bone injury is depicted in Figure 3.

3.2.3 | Association between reported reduction in CHO intake and the use of fasted training with self-reported bone injury incidence

A negative binomial regression model determined that the incidence rate of bone injury was similar in those who reported reducing CHO intake compared to those who had never used it ($p = 0.82$ and CI: 0.60–1.49) or those who had used it in the past ($p = 0.17$ and CI: 0.39–1.18). However, the incidence of bone injury was 1.61 times higher in those who reported using fasted training compared to those who had never used it ($p = 0.04$ and CI: 1.02–2.54), see Table 1.

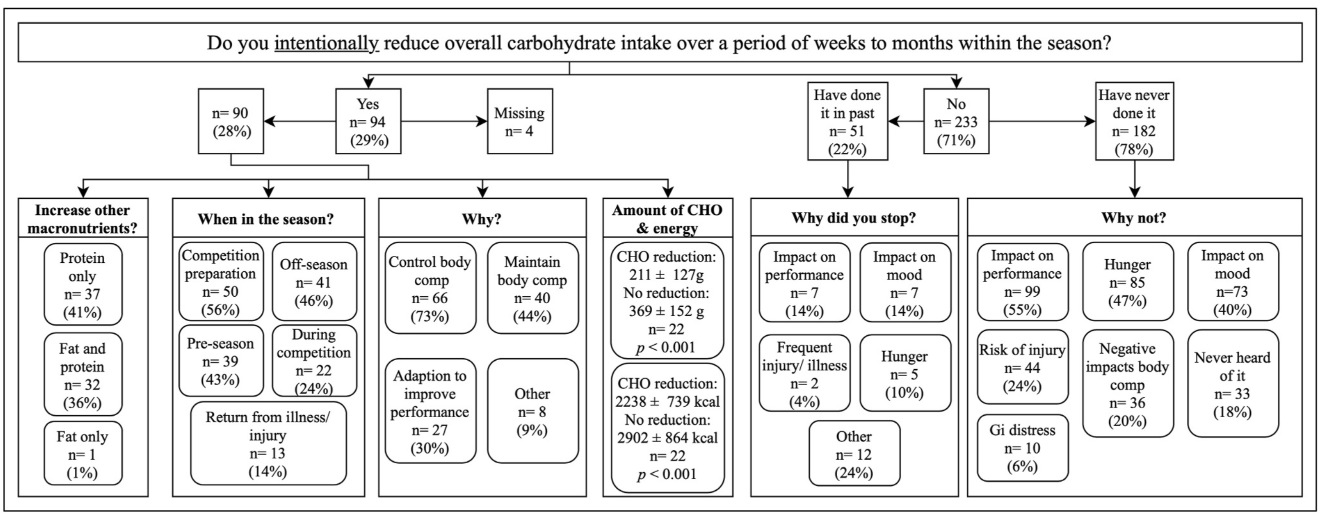

FIGURE 1 The prevalence of the use of periods of CHO restriction, with a schematic outline giving further details on its use and reasons for using this practice.

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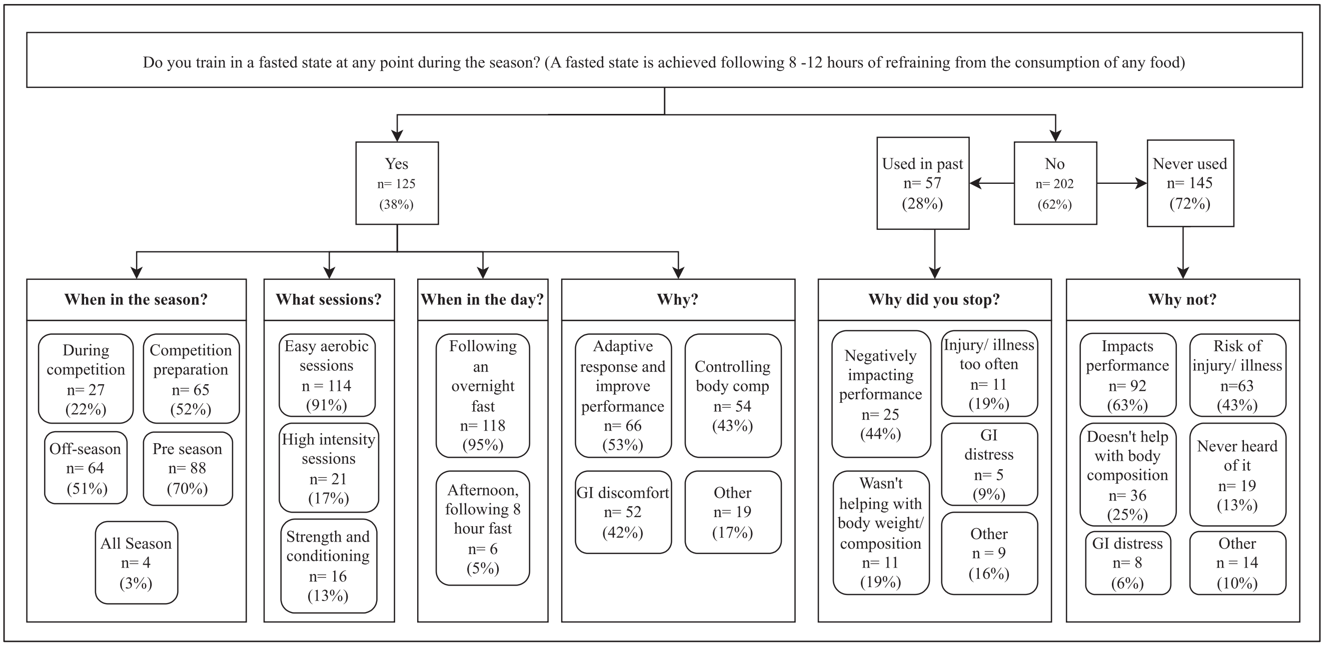

FIGURE 2 The prevalence of the use of fasted training, further details on its use and the reasons for using it.

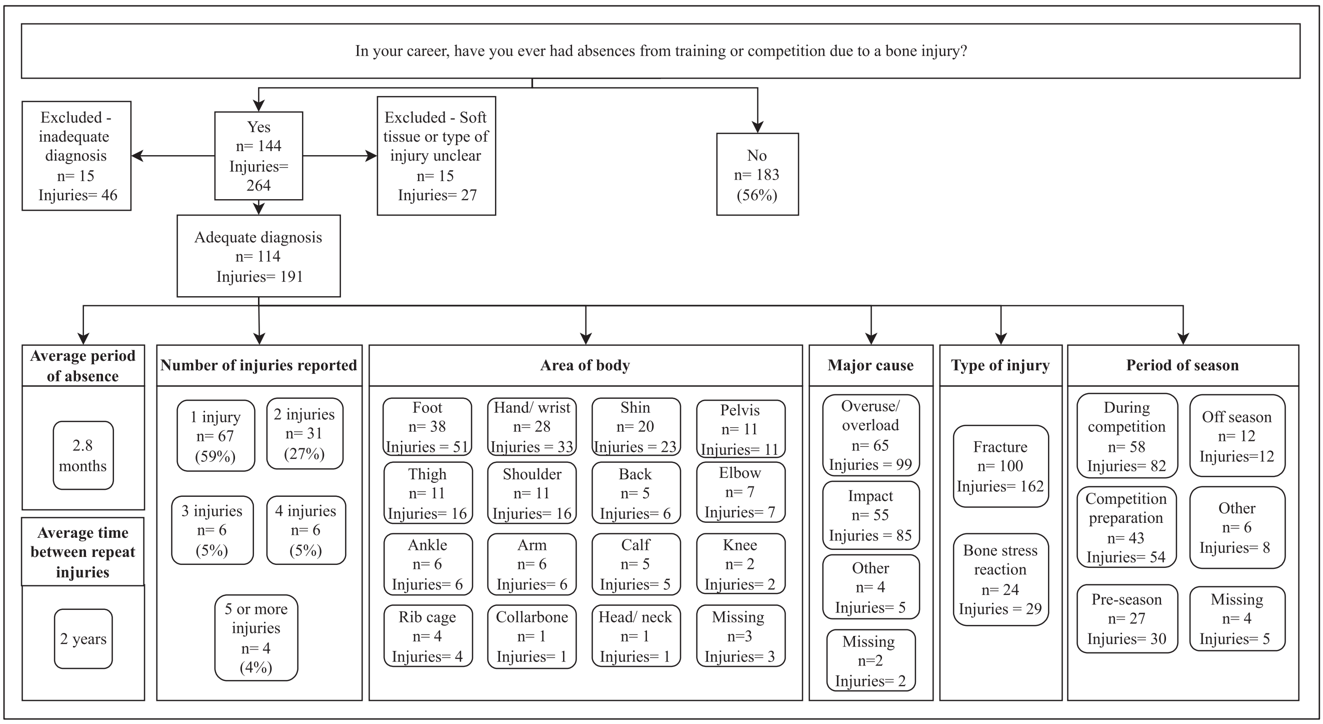

FIGURE 3 The incidence of bone injury and further details on the number of injuries reported, average time between repeat injuries, average period of absence from training or competition due to an injury, area of body in which the injury occurred, the cause of the injury, the type of injury and the period of the season in which the injury occurred.

4 | DISCUSSION

The prevalence of self-reported use of intentionally reducing overall CHO intake over a period of weeks to months in elite endurance-based athletes was 28% which is similar to the elite cohort in a recent study when participants were asked if they reduce CHO intake periodically (Heikura et al., 2018). The use of fasted training is also prevalent among our cohort (38%). This prevalence is similar to the prevalence of use in pro level athletes (29%) reported in a recent study (Rothschild et al., 2020). We also report that a large proportion (44%)

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TABLE 1 Negative binomial regression model predicting bone injury incidence.

Parameter	B	SE	X^2 (df)	p	IRR	95% CI
Intercept	*−1.28*	*0.39*	*10.76*	*< 0.001*	*0.28*	*0.13–0.60*
Currently use fasted training (ref: never used fasted training)	0.48	0.23	4.15	0.04	1.61	1.02–2.54
Used fasted training in the past (ref: never used fasted training)	0.26	0.28	0.83	0.36	1.29	0.74–2.25
Currently use periods of reduce CHO (ref: never used reduced CHO)	−0.05	0.23	0.05	0.82	0.95	0.60–1.49
Used periods of reduced CHO in past (ref: never used reduced CHO)	−0.39	0.28	1.89	0.17	0.68	0.39–1.18
Biological sex–Female (ref: Male)	−0.14	0.20	0.50	0.48	0.87	0.59–1.28
Athlete level–World (ref: National)	0.24	0.29	0.71	0.40	1.27	0.44–1.26
Athlete level–International (ref: National)	0.10	0.23	0.19	0.66	1.11	0.43–1.19
Sport–Triathlon (ref: Athletics)	−0.80	0.31	6.65	0.01	0.45	0.25–0.83
Sport–Swimming (ref: Athletics)	−1.07	0.42	6.39	0.01	0.34	0.15–0.79
Sport–Rowing (ref: Athletics)	−1.21	0.39	9.51	<0.001	0.30	0.14–0.64
Sport–Cycling (ref: Athletics)	−0.19	0.27	0.51	0.48	0.82	0.49–1.40
Sport–Boxing (ref: Athletics)	−0.48	0.43	1.26	0.26	0.62	0.27–1.43
Years of dedicated training?	0.08	0.02	12.75	<0.001	1.08	1.04–1.13
Hours per week of training	0.02	0.02	0.79	0.37	1.02	0.97–1.07

Note: Likelihood–ratio chi-square test for model: X2 (df) = 58.05 (13) and p < 0.001.
Abbreviations: B, beta coefficient; CI, confidence interval; IRR, i0ncidence rate ratio; SE, standard error.

of athletes have suffered a radiographically confirmed bone injury during their career and the concurrent use of fasted training was associated with bone injury incidence, although we do not have data to confirm whether these athletes were training in a fasted state at the time of the injury and this association does not imply causation.

Although it has been suggested that reducing CHO intake can promote adaptations that are beneficial for the endurance phenotype and potentially improve performance, only 29% of those who reported doing it in this study reported doing so for this reason (n = 27). In fact, the main reason why respondents either stopped using it or never used it was because they believed it negatively impacts performance. The most common reason given for using this practice was to maintain or control body composition possibly in part due to the prevalence being significantly higher in boxing compared to other endurance-based sports. The use of restricted dietary intakes for this purpose is commonplace in combat sports with 60%–80% of athletes reportedly engaging in it (Barley et al., 2019). The extent of change in body composition in combat sports can be severe as it has been shown that, over an 8-week period, severe perturbations to energy balance can lead to an 18% reduction in body mass in an elite mixed martial arts fighter (Kasper et al., 2019). However, there remains questions as to how such dramatic changes in body composition can impact performance and, if repeated frequently, what the potential negative health consequences are including bone health (for review see Lakicevic et al., 2021). In other endurance sports, such as athletics, more modest changes (2%–4%) in body composition can be beneficial in ensuring that an athlete can maximise performance when needed but is not exposed to the negative consequences of reduced body composition for extended periods of time (Stellingwerff, 2018). In the current study, athletes were also asked if they increased consumption of other macronutrients when they reported reducing CHO intake and a large proportion (73%) indicated that they increased protein consumption. This aligns with recommendations and recent evidence, suggesting that increasing protein intake during reduced energy intake (e.g., weight cutting) in athletes can help maintain fat free mass (Hector & Phillips, 2018).

Only a small proportion of participants (n = 21, 22%) who reported reducing CHO intake were able to report the amount of CHO (g) and energy (kcal) that they consume during a period of carbohydrate restriction and during a period of non-restriction. Additionally, four participants indicated that they consumed >7 g kg body mass $(BM)^{-1}$.day^{-1} CHO when they are reducing CHO intake which would be still considered a high CHO intake and of those participants who could report the amount of CHO they consume during a period where they are not making any intentional restrictions to their diet indicated that they consumed <5 g kgBM^{-1}.day^{-1} which is the recommended amount for 'light skill based activities' (Thomas et al., 2016). This highlights a gap between an athlete's perception of intentionally reducing CHO intake and whether the diet is actually low in CHO. Additionally, when participants were asked to identify foods that are rich in CHO, all correctly identified grains and a vast majority identified starchy vegetables. However, only 12% indicated that dairy, such as milk, cheese and yoghurt, are CHO rich sources. This is a particularly relevant to the aims of this study when the nutrient profile of dairy products and their ability to support bone

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health is considered. The above highlights a potential gap in athlete's knowledge regarding CHO and food choice behaviour which has been highlighted previously among people who follow low CHO diets (Churuangsuk et al., 2020). It also highlights a potential lack in understanding on the part of the athlete as to the CHO requirements of their sport and how to appropriately periodise nutrition based on the volume and intensity of a given training session or period of training.

In comparison to the reported reduction of overall CHO intake, the prevalence of fasted training was higher (38%) and the rationale for use was evenly spread across controlling body composition and promoting an adaptive response with some also suggesting time constraints and GI discomfort as a reason for training in the fasted state. The negative impact upon performance was the most frequently cited reason why athletes stopped or had never used fasted training, and a number of participants also cited illness or injury concerns as the reason why they do not currently or have never used fasted training. The evidence for the use of fasted training to alter body composition is equivocal; in fact, in a study that examined changes in fat mass and fat free mass following four weeks of volume matched fasted versus fed aerobic exercise in young women following a hypocaloric diet, similar changes in body composition were shown (Schoenfeld et al., 2014). However, another study in elite under-23 cyclists reported that there was a 2% reduction in body weight and 1.1% reduction in fat mass following 4 weeks of time restricted eating with no change observed in a control group (Moro et al., 2020). In addition, although there is some evidence to suggest that training in the fasted state can promote an adaptive response through upregulation of signalling cascades involved in mitochondrial biogenesis, substrate utilisation and autophagy, little evidence is reported on purported benefits (or lack thereof) from long-term use (Aird et al., 2018).

This study identified a high prevalence of fasted training in triathlon, cycling and athletics. This may be due to the purported benefits in fat utilisation and oxidation (Vieira et al., 2016), and this finding may be more relevant to endurance athletes competing in events over several hours versus their counterparts in swimming or rowing who compete in much shorter duration events. It may be also due to time constraints associated with training across three different disciplines in triathlon, and this was a common reason cited for the use of fasted training in this study. Men were also significantly more likely to use fasted training compared to women, although women were significantly more likely to have used it in the past. This is speculatively due to an awareness or increased susceptibility of female athletes to the consequences of LEA and REDs which has been discussed extensively in scientific and lay media (Charlton et al., 2022; Mountjoy et al., 2018; Tulloch, 2021).

Endurance-based sports and training can elevate several risk factors for bone injury incidence. For example, here, we have seen a high prevalence of bone injury in boxing (53%). Although the majority of these were classified as 'impact' injuries, the role of high training loads which can lead to an accumulation of bone micro-damage and prolonged periods of LEA due to an emphasis on leanness and body weight, also pose a risk to bone (Beck & Drysdale, 2021). In addition, the mechanical loading patterns are less osteogenic than in sports that involve multidirectional high impact movements (Tenforde et al., 2018). Forty-four percent of respondents reported a bone injury at some point in their career, with the foot reported as the most common area of the body for an injury to occur, a fracture was the most common type of injury and the cause of injury was quite evenly distributed between impact and overuse/overload. These observations are similar to those in a study carried out across 25 NCAA sports, which showed that the rates of bone stress fracture are highest in endurance sports and occur most often in the foot or lower leg (Rizzone et al., 2017). In exploring the cause of injury further, it was found that an overuse or overload injury was more commonly reported in athletics, while an impact injury was most likely to be reported in cycling. This make sense when the biomechanical properties and differing risk factors associated with these two sports are considered. High volumes of running typically carried out in elite athletics can lead to an accumulation of bone micro-damage due to the repetitive ground reaction force associated with it. If repeated frequently without adequate recovery, time or nutritional support to allow a bone remodelling cycle to complete an accumulation of micro-damage may lead to a localised compromise in bone strength, a bone stress reaction and/or a fracture due to overuse or overload (Warden et al., 2014). Cycling is a weight supported activity which may lead to a compromise in BMD or bone strength due to the inadequate mechanical loading to stimulate an osteogenic response with low BMD been shown to be prevalent in professional cyclists across multiple career timepoints (Hilkens et al., 2023). Therefore, the epidemiology of fractures in cyclists is different and despite having lower BMD in comparison to reference controls, injuries are only likely to present themselves upon hard impact as a result of crash or fall when weakened bones cannot withstand the acute trauma.

It is also important to consider that dietary practices that are prevalent in endurance-based sport, such as reducing CHO intake and fasted training, may be associated with the incidence of bone injury, as bone is a nutritionally modulated tissue (Sale & Elliott-Sale, 2019). Herein, we have shown that the incidence rate of bone injury in those who reported reducing CHO intake was similar to those who have reported never reducing it or those who reported having reduced it in the past. However, for reasons previously mentioned, it is difficult to determine if those participants who indicated that they reduce CHO are in fact reducing it and whether the CHO intake amounts reported by participants are appropriate for their training and competition discipline. This may explain in part why the current study was unable to identify a significant association between the reported use of this practice and bone injury incidence. The incidence of bone injury was 1.61 times higher in those who currently use fasted training compared to those who have never used it. Fasted training as a concept is much easier to interpret, understand and implement when compared the reduction of CHO intake as to achieve it one needs only to abstain from the consumption of food for 8–12 h in advance of a training session. Although training in the fasted state can form part of an approach that aims to drive metabolic adaptation, it can potentially lead to a reduction in 24-h energy

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intake and this has been shown in active males (Bachman et al., 2016). If a reduction in 24-h energy intake is not the intended outcome of using fasted training, it could potentially lead to a state of LEA which if repeated frequently may act in tandem with some of the other known risk factors for bone injury incidence and poor bone health outcomes in elite endurance-based athletes.

The current study is limited by the fact that it relies on self-reported information from athletes which we have demonstrated presents a challenge due to varying degrees of understanding and the gap between an athlete's perception and reality when it comes to undertaking dietary manipulation. Future studies should aim to take a more prospective approach although the authors recognise the challenges and limitations of such a design, especially in an elite athlete.

5 | CONCLUSION

In conclusion, we have shown that the self-reported use of intentionally reducing CHO intake and fasted training are prevalent in endurance-based athletes. Although a direct causal link between the use of dietary practices that reduce the CHO availability and incidence of bone injury cannot be drawn, it provides a good basis for future investigations of the potential mechanisms that could explain the effect. Apart from the primary and secondary aims of the study, an equally interesting outcome has been athlete awareness of CHO intake. Applied practitioners should aim to give athletes a better understanding of the nutritional, especially CHO, demands of elite endurance-based sport. As stated previously, there are many consensus statements and high-quality research studies that do not always necessarily translate into applied practice. This provides future direction for both applied practice and studies interested in athlete nutrition knowledge and food choice.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

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