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Energy and macronutrient intake in athletes

Increased carbohydrate availability effects energy and nutrient periodisation of professional male athletes from the Australian Football League

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Energy and macronutrient intake in athletes

Abstract

This research aims to explore the effect of increased carbohydrate availability intervention on energy intake and distribution in professional Australian Football athletes. Six 24-h energy and macronutrient intakes were quantified (n= 19 males; age 24 ±4 y, stature 187 ±8 cm, mass 87 ±9 kg) using photographic food diaries and Foodworks analyses. Energy expenditure was estimated for the same period using GeneActiv accelerometers. During three control days, athletes had ad libitum access to food, while the three intervention days increased carbohydrate availability, through greater prompting and access to carbohydrate foods. Daily energy intake was higher during intervention (185 ±40 kJ/kg/d) compared with control (172 ±31 kJ/kg/d; $p<0.05$) but remained below estimated expenditure, and carbohydrate intake was also greater with intervention (5.0 ±0.2 g/kg/d) than control (4.0 ±0.2 g/kg/d; $p<0.05$). Expenditure was highest during the morning which coincided with lowest intake on all days, while the intervention was associated with greater carbohydrate intake in the morning (0.6 g/kg, $p< 0.05$) compared with control. Increasing availability of carbohydrate during high-load training generated a modest increase in carbohydrate and energy intake, and the intervention was most effective in improving carbohydrate intake during mornings.

Novelty Bullets

- Increased access and provision of carbohydrate foods increased carbohydrate consumption and energy intake on high training load days.
- Daily distribution of energy intake can be modified through actively promoting carbohydrate consumption.

Keywords: Nutrient timing, macronutrient, sports nutrition, energy expenditure, dietary intake, GeneActiv accelerometer, Australian Football, Nutrient periodisation

Energy and macronutrient intake in athletes

Introduction

Maintaining energy balance by closely matching energy intake (EI) to daily energy expenditure (EE) is a typical goal for elite athletes to promote recovery and performance for training and competition. The daily distribution of the energy and macronutrient intake of athletes is often determined by specific sports nutrition guidelines and training/competition demands (Thomas et al., 2016). For example, team sport athletes such as Australian Footballers are recommended to consume sufficient carbohydrate to ensure adequate pre-exercise muscle glycogen content to reduce fatigue and optimise cognitive function during prolonged periods of high intensity, intermittent anaerobic and aerobic exercise (Baker et al., 2015). Moreover, recommendations suggest the provision of exogenous carbohydrate as additional energy substrate for high-intensity exercise, extends endurance capacity and improves ability to perform repeated sprint efforts (Jeukendrup, 2011, Holway and Spriet, 2011). However, previous studies have repeatedly shown that elite athletes often fail to achieve an EI that is equivalent to their EE (Hill and Davies, 2002, Fudge et al., 2006, Bescos et al., 2012, Vogt et al., 2005, Geesmann et al., 2014, Cho, 2014, Burke, 2001, Baranauskas et al., 2015, Deutz et al., 2000, Barrero et al., 2014, Praz et al., 2014, Thomas et al., 2016). Studies capturing external training loads of Australian Football athletes have shown an average of 7323 ±2853 m per session ~25 % of which is high velocity running (>14.4 km/h) (O'Connor et al., 2020). Given team sport athletes routinely undertake prolonged bouts of high intensity training, inadequate energy intake is likely to induce an energy deficit leading to compromised muscle glycogen concentrations and low energy availability (Vigh-Larsen et al., 2021, Routledge et al., 2019). Therefore, carbohydrate is an essential energy substrate and contributor to total EI during these training sessions and to ensure physical preparation for this professional team sport.

Protein and fat intakes of athletes generally meet sport nutrition recommendations but carbohydrate intake is routinely reported below levels advocated to promote optimal performance and recovery in team sports such as rugby and Australian Football (MacKenzie et al., 2015, Black et al., 2018, Jenner et al., 2018). This is of primary concern for sports performance, given the potential impact of carbohydrate intake on the quality of training (Thomas et al., 2016). Commencing team sport training with adequate muscle glycogen content, and exogenous carbohydrate intake during a training session, has the potential to enhance training quality and reduce fatigue. Accordingly, sports nutrition recommendations include a minimum of 5 g carbohydrate per kilogram body weight per day for a moderate exercise program (e.g., ~1 h/day), a training demand routinely exceeded in professional team sports (Thomas et al. 2016). Importantly, our understanding of carbohydrate intake during and between sessions for different periods of intake throughout a single day when team sports training load is high remains deficient.

Moreover, to the best of our knowledge no previous studies have characterised the effect of increased availability of carbohydrate on total EI and the daily distribution of energy and macronutrient intake in team sport athletes. The aims of this study were to determine 1) if an increase in access to carbohydrate foods facilitates greater carbohydrate and dietary EI in Australian Football athletes on training days with the highest training loads and 2) if increased carbohydrate availability alters the distribution pattern of daily energy and macronutrient intake. We hypothesised that increasing availability of carbohydrate containing foods before, during and after training sessions would significantly increase carbohydrate and EI in Australian Football athletes and that higher energy/carbohydrate intake would coincide with periods of greatest EE.

Energy and macronutrient intake in athletes

Materials and Methods

Participants

Nineteen male athletes (age 24 ±4 y, stature 187 ±8 cm, mass 87 ±9 kg, skinfolds 41 ±8 mm [sum of seven]) from a professional Australian Football League (AFL) team volunteered to participate in the study. Eight out of 114 observation days from six players were excluded from data analysis (accelerometer failure, n= 5; illness, travel and missed meals, n= 3). Players were each part of the same team and training together at the same venue and approximate time of day. Participants reported for their commonly termed "main training days", which represent days generating the highest training loads, at 0730 for a team meeting followed by pre-training strapping, physiotherapy or an individual dynamic warm up. Football training was undertaken for ~2.5 h immediately followed by a one-hour lunch break. Thereafter, strength resistance training sessions of ~1 h in duration were undertaken and players could voluntarily leave the training facility following its completion (Figure 1).

Insert Figure 1.

The experimental period included days on which high-load training sessions were scheduled each week for a three-week period during pre-season preparation in December 2018. Each high-load training day was also compartmentalised to a morning period defined as 0600-1159 h, afternoon defined as the time between 1200-1759, and evening 1800-2400 h. Prior to commencement of this study ethics approval was obtained through Bond University Human Research and Ethics Committee (BS02092). All participants provided their written informed consent prior to taking part in the study.

Food availability intervention

Energy and macronutrient intake in athletes

The experimental design compared three high-load training days with increased carbohydrate availability (ICA) to three equivalent control days with regular/habitual access to carbohydrate (CONT) on energy and macronutrient intake. During the first three training days (CONT), there was regular food availability and athletes had their normal ad libitum access to foods suitable for a high-performance training environment. During the subsequent ICA intervention days athletes had the same access to their regular foods but players were informed of the increased availability of, and easier access to, carbohydrate containing food for them to consume. This information was provided verbally by the researcher to enable them to increase their carbohydrate intake (Supplementary table S1). Specifically, there were four extra "grab and go" stations set up, one on the football field, another two next to the changerooms and the strapping area, and the remaining station set up in the resistance training area. Carbohydrate containing foods and beverages were also actively offered during the training session breaks which did not occur during CONT. Additionally, the carbohydrate content of the main lunch meal and snacks were increased compared to CONT via a greater variety of carbohydrate foods offered before, during and after trainings. These additional carbohydrate foods/drinks included bread and cereal products, confectionary, baked goods, dairy snacks and high energy beverages with athletes verbally encouraged to consume. Interventions were undertaken during the time periods the participants were at the training facility. The final component in the ICA intervention was a take home high carbohydrate meal when departing at the conclusion of the training day.

Estimating Energy Expenditure

Energy expenditure was estimated during each 24-h (0000-2400 h) period using GeneActiv tri-axial accelerometers (Activeinsights Limited, Kimbolton, Cambridgeshire, UK). These devices have previously been compared for intra and inter-device coefficient of variation (1.4% and

2.1%, respectively), and have been shown to be valid and reliable in estimating daily energy expenditure in the general population (Esliger et al., 2011, Dillon et al., 2015). In addition, prior to undertaking the present study we assessed validity for use of the Geneactiv during high intensity physical activity against the criterion measure of indirect calorimetry in controlled laboratory conditions. The standard error of the estimate of the GenActiv for calculating metabolic equivalents (METs) during high-intensity running was 1.77 METs ($r^2 = 0.64$, $p < 0.0001$).

After each day of data collection, the GeneActiv accelerometers were downloaded onto the analysis platform provided by Activeinsights LTD (version V.3.2, United Kingdom) and the regression equation developed during laboratory validation against indirect calorimetry ($y = 0.001x + 4.4329$; Where y represents metabolic equivalents and x is GeneActiv counts) was applied to periods of activity greater than the Activeinsights software maximum activity band (>7 METs). Given the limited data available on the capacity for accelerometers to estimate EE during resistance training, 5 mets·min^{-1} was applied to resistance training sessions (Ainsworth et al., 2011, Zanuso et al., 2016). Ratings of perceived exertion (RPE) were obtained 10-30 min following the completion of each training session using Borg's CR-10 scale.

Estimating energy and macronutrient intake

On each high-load training day athletes completed a 24-h photo food diary (0000-2400 h). The method required participants to take pictures using personal smartphones of all food and fluid at the time of ingestion (Campagnolo et al., 2017). Video recordings of trainings were annotated to capture food intake during a training session and individualised drink bottles were monitored for type and quantity of fluid consumption. Photograph images were stored and categorised by day and time. They were then allocated to either morning (0600-1159), afternoon (1200-1759)

Energy and macronutrient intake in athletes

or evening (1800-2400) time periods. Two dietitians undertook all food and beverage preparation which enabled all the ingredients in meals consumed by the athletes at both the training facility and home over a 24-h period to be recorded. Dietary intake was analysed by a qualified dietitian using Foodworks (Xyris software, version 9, Australia) to determine total energy and macronutrient intake over each 24-h period of the six days data collection. The second dietitian resolved any queries of food content or portion size and precision in the analysis of energy intakes from repeated measures of food consumed at meals was established as a coefficient of variation of 4.4% (n= 20).

Statistical Analysis

The mean data for each three-day CONT and ICA period were analysed for differences using paired t-test. Comparison of EI and EE on each of the six high-load training days, and the daily distribution pattern of macronutrients and EI and EE, were analysed using two-way repeated measures analysis of variance with Sidaks multiple comparisons post-hoc test (GraphPad Prism Version 8.3.0). The level of significance was $p<0.05$ and data are expressed as mean ± standard deviation. Cohen's effect size (d) was also calculated for each comparison and interpreted using established thresholds of 0.2 as a small effect, 0.5 a moderate effect, and 0.8 a large effect.

Results

Daily macronutrient intake

Mean carbohydrate intake for each three-day experimental period ranged from 1.3-5.5 g/kg/d during CONT and 1.3-6.2 g/kg/d throughout the ICA period. The mean carbohydrate intake was significantly higher across the three days with increased carbohydrate availability (ICA 5.0 ±0.2 g/kg/d) compared with normal food availability (CONT 4.0 ±0.2 g/kg/d) and this was a large effect ($p< 0.05$, d= -0.85; Figure 2A).

Energy and macronutrient intake in athletes

Insert Figure 2.

Mean protein intake ranged from 1.8-3.4 g/kg/d during CONT and 1.5-3.1 g/kg/d throughout the ICA three-day intervention periods. The mean protein intake was higher throughout CONT (2.7 ±0.1 g/kg/d) compared with ICA (2.5 ±0.3 g/kg/d) and this was a moderate effect ($p < 0.05$, $d = 0.5$; Figure 2B).

Mean fat intake ranged from 0.9-2 g/kg/d across the three CONT days and 0.9-2.5 g/kg/d throughout the intervention period. Fat intake was not different during CONT (1.6 ±0.5 g/kg/d) compared with ICA (1.5 ±0.3 g/kg/d) but was lower across the three days with increased food availability during the ICA which was a small effect ($p = 0.17$, $d = -0.3$; Figure 2C).

Daily macronutrient intake distribution

There were main effects for intervention ($p < 0.01$) and time of day ($p < 0.0001$) for mean carbohydrate intake across the day during the three-day experimental period. The CONT and ICA intervention period showed carbohydrate intake was greatest in the afternoon (CONT 1.9 ±0.7 g/kg; ICA 2 ±0.9 g/kg) compared to morning and evening intakes (CONT 0.8 ±0.4 g/kg and 1.3 ±0.5 g/kg; ICA 1.3 ±0.5 g/kg and 1.5 ±0.7 g/kg respectively) (Figure 3A). There was a significant difference between mean carbohydrate intake during the morning period that was also evident as a large effect for higher carbohydrate intake with ICA compared with CONT (0.6 g/kg, $p < 0.05$, $d = 1.12$)

Insert Figure 3.

Energy and macronutrient intake in athletes

Furthermore, there was a time of day × intervention interaction for protein intake ($p< 0.05$) and afternoon protein intake was greatest (CONT 1.4 ±0.2 g/kg; ICA 1.1 ±0.4 g/kg) compared to morning and evening intakes (CONT 0.4 ±0.2 g/kg and 1 ±0.3 g/kg; ICA 0.5 ±0.2 g/kg and 0.9 ±0.3 g/kg respectively). There was a significant decrease in protein intake in the afternoon period for ICA compared with CONT and this was a large effect (-0.2 g/kg, $p< 0.05$, $d= -0.94$) that was not evident during morning or evening periods (Figure 3B). There was a main effect of time of day ($p< 0.0001$) and mean fat intake for both CONT and ICA was highly comparable in the evening (0.7 ±0.3 g/kg) and afternoon (0.6 ±0.2 g/kg) but lower in the morning period (0.2 ±0.1 g/kg). Accordingly, there were no differences in fat intake and trivial effect sizes between CONT and ICA at all times (Figure 3C).

Daily energy intake/expenditure and rating of perceived exertion

Mean EE during the CONT and ICA three-day periods was not different ($p=0.8$), due to the matching of duration, type and number of daily sessions. The mean EI during the three day experimental periods was higher during the ICA intervention (185 ±40 kJ/kg/d) compared with CONT (172 ±31 kJ/kg/d), although this difference was only a moderate effect (13 kJ/kg/d, $p< 0.05$, $d= 0.4$; Figure 4A). EI ranged from 87-228 kJ/kg/d across the three days of ICA intervention and 84-244 kJ/kg/d throughout the CONT period. There were main effects for individual days ($P< 0.05$) and EI versus EE ($p< 0.0001$). A significantly lower EI compared to EE occurred on every day except for the final ICA intervention day (-26 kJ/kg/d; $p= 0.13$, $d= 0.09$). However, there was no significant difference in athlete ratings of perceived exertion between ICA and CONT days (ICA 7.4 ±0.1; CONT 7.6 ±0.4 arbitrary units). The energy deficit on the three CONT days was -63 kJ/kg/d ($p< 0.0001$, $d= -2.16$), -49 kJ/kg/d ($p= 0.0001$, $d= -0.73$), and -36 kJ/kg/d ($p< 0.01$, $d= -1.13$) and on the remaining two ICA intervention days was -44 kJ/kg/d ($p< 0.01$, $d= 0.01$) and -35 kJ/kg/d ($p< 0.01$, $d= -0.52$ Figure 4B). Athletes were in low energy availability on the high load training days with energy availability range across the CONT days 99-117 kJ/kg FFM (Fat Free Mass)/d whereas the ICA days ranged from 113-131 kJ /kg FFM/d.

Insert Figure 4.

Daily energy intake and expenditure distribution

There were main effects for time of day ($p < 0.0001$) and intervention ($p < 0.01$) but no interaction ($p = 0.6$) for mean EI during morning, afternoon and evening periods. Both CONT and ICA intervention periods showed morning energy intakes were lowest (CONT 29 ±12; ICA 39 ±12 kJ/kg kJ/kg) compared with afternoon (CONT 73 ±16 kJ/kg; ICA 75 ±29 kJ/kg) and evening EI (CONT 66 ±23 kJ/kg; ICA 69 ±26 kJ/kg; Figure 5A). In contrast, main effects for EE time of day ($p < 0.0001$) show mean daily EE was highest in the morning period in both the control and intervention (CONT 120 ±8 kJ/kg; ICA 118 ±8 kJ/kg) with a stepwise decrease in EE in the afternoon (CONT 60 ±5 kJ/kg; ICA 62 ±6 kJ/kg) and evening periods (CONT 37 ±5 kJ/kg; ICA 37 ±4 kJ/kg; Figure 5B).

Insert Figure 5.

Discussion

The primary aim of this study was to ascertain if ICA facilitated an increase in carbohydrate intake and EI in Australian Football athletes during a high-load training day. We showed that increasing the availability of carbohydrate containing food and beverages before, during and after training for team sport athletes was associated with a modest increase in carbohydrate and total EI. Moreover, the intervention was most effective in promoting carbohydrate intake during the morning and a greater carbohydrate intake appeared to displace some protein intake typically consumed in the afternoon, but protein intake remained above athlete recommendations. Nonetheless, despite the increase in carbohydrate intake observed in the early part of the day, the pattern of EI and EE during high-load training days showed an inverse relationship where EI was lowest when estimated energy demand was highest.

The results of the current study indicate that greater access to carbohydrate containing foods and beverages can promote an increase in carbohydrate and energy intake of team sport athletes and reduce the energy deficit between EE and EI. Whilst the increase in carbohydrate and total EI was modest, it was significant, and effect size statistics show the increase in carbohydrate availability appeared to "close the gap" towards energy balance on days athletes were exposed to very high training loads. If "pre-fuelling" prior to training sessions, or greater carbohydrate intake during exercise, is a trainable factor for team sport athletes this could facilitate additional energy intake toward achieving energy balance. Whilst we acknowledge there are limitations in the precision of measuring EI and EE to determine energy balance, our findings are in agreement with previous studies in team sport athletes, where athletes have been shown to meet or exceed sports nutrition recommendations for protein and fat intake during training and competition, but carbohydrate and EI are inadequate (Burke et al., 1991, Ebert, 2000, Jenner et al., 2019, Routledge et al., 2020, MacKenzie et al., 2015). Consequently, the increase in carbohydrate in the present study has the capacity to improve the quality of training on high-load training days. However, it is unclear if the short intervention of increased carbohydrate availability and active promotion of consumption would be sufficient to change athlete behaviour, or whether an enduring, decisive strategy is required to maintain greater carbohydrate intakes on high load training days. Regardless, the increase in carbohydrate intake is an important practical outcome of the present study because current sports nutrition recommendations suggest EI should aim to match EE to improve training performance and recovery (Thomas et al., 2016).

(Thomas et al., 2016).

Although the ICA intervention improved energy and carbohydrate intake it had limited impact on the distribution of consumption. While ICA augmented carbohydrate intake early in the day, the morning period remained the lowest period of macronutrient intake for the Australian Footballers, which has also been shown in other athlete populations (Van Erp-Baart et al., 1989, Burke et al., 2003, MacKenzie et al., 2015). Sports nutrition recommendations suggest athletes should employ strategies to ingest additional carbohydrate at the time of day where energy needs are greatest, and field-based skill, tactical and conditioning training in the current study was undertaken early in the day (Thomas et al., 2016). Low carbohydrate and EI in the mornings may be related to reduced time availability if athletes prioritise sleep for recovery above early waking to consume a substantial breakfast. Alternately, team sport athletes have previously been shown to consume only 3-5% of their total daily EI during training sessions, much less than sports such as cycling where ~50% of total EI may be consumed during exercise (Saris et al., 1989, Burke et al., 2003). It is important to note Australian football athletes have opportunities to increase intake during competition due to quarterly breaks, on field fluid provision and frequent player rotations. Conversely, the opportunities for food and fluid intake during training sessions are not well-defined and may vary between sessions. High intensity exercise and/or occurrence of physical collisions, may also result in avoidance of food due to gastric upset which may contribute to inadequate EI (Birkenhead and Slater, 2015). Moreover, these Australian football athletes recorded the highest energy, carbohydrate and protein intake in both CONT and ICA during the afternoon, when the less metabolically stressful and shorter duration resistance training session was undertaken. Late afternoon and evening energy intake represents recovery nutrition for subsequent training days. Given that carbohydrate intake was only increased in the morning it may be reasonable to suggest that larger, satiating meals consumed during the afternoon/evening dictates that additional carbohydrate provision in this period is unrealistic. Therefore, specific interventions in the morning and throughout field-based training sessions may be most beneficial if ingestion opportunities can be increased or constraints reduced to further increase energy intake during this period of the day.

Previous studies in athletes have shown variations in energy and macronutrient consumption, and also meal timing and frequency across the day (Burke et al., 2003, MacKenzie et al., 2015). Of note, Burke and colleagues (2003) report endurance athletes had substantially higher intakes of carbohydrate than other sports, including team sport athletes, and were among the athletes most likely to consume carbohydrate during and after training sessions. In contrast, research undertaken in various football codes shows carbohydrate intake is often lower than recommended, where mixed-mode, multiple daily training sessions are undertaken. It appears athletes may seek to compensate for inadequacies in dietary intake on days with highest training demands by increasing caloric intake on lower training load days (MacKenzie et al., 2015, Black et al., 2018, Jenner et al., 2018). However, it is unclear if athletes were in any prolonged period of energy deficit because body composition data were only obtained near the commencement of the study, as these were routine sport science program measures undertaken on an independent timeline. The restrictions of a professional sporting environment also resulted in being unable to randomize the ICA intervention, which are both limitations of the present study. Finally, the inability to target ad libitum energy intake when athletes were unsupervised was restrictive. Together, these factors represent limitations to the present study. Nonetheless, despite the constraints of working with professional athletes our findings indicate a greater emphasis on education and/or an extended food provision program may be needed to promote carbohydrate consumption and increase daily energy intake in team sport, when professional athletes are in attendance or away from their training facility. However, consideration should be given to the idealistic nature of these recommendations as often resources such as support staff availability and funding can provide barriers to the success of these strategies.

Interestingly, when carbohydrate intake increased as a result of ICA, protein intake decreased but was not compromised relative to athlete protein recommendations. Australian football athletes have been shown to exceed recommended protein intakes (2.6 ±0.2 g/kg/d) and increasing the carbohydrate contribution to EI to displace some protein intake may be beneficial for enhancing the quality of training. This would be advantageous given excessive protein intake merely increases protein oxidation (Moore et al., 2009) and achieving appropriate protein distribution across high-load training days with multiple sessions is likely beneficial for optimal protein synthesis and net protein balance (Areta et al., 2013, Moore et al., 2012).

Conclusion

We have shown for the first time the practical outcomes of a strategic carbohydrate intervention on the distribution and total EI of professional Australian Football athletes on their highest pre-season training load days. The greater carbohydrate availability was associated with a significant increase in carbohydrate and EI but did not enable the athletes to increase their EI substantially enough to match their EE. This finding characterises barriers in meeting nutrition recommendations when multiple training sessions and high daily training loads are undertaken and is an important area for future research, particularly in team sports where training loads vary significantly from day to day. We also present novel data showing limited EI early in the day and a clear imbalance in the daily pattern of distribution that is low when energy demand is highest. Given team sport athlete's do not appear to periodise their daily EI, strategies such as additional "pre-fuelling" in the 24-h prior to high-load training days and/or more explicit intervention before/during morning training sessions may be required to further improve carbohydrate intake. Nonetheless, our results provide support for ensuring greater availability and prompting for carbohydrate intake in team sport athletes to increase EI and reduce energy deficit during training days when energy expenditure is high.

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Conflicts of Interest

The authors declare they have no conflicts of interest.

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Energy and macronutrient intake in athletes

Figure Captions

Figure 1. Schematic to show timeline of athlete daily activities

Figure 2. Estimated average daily relative carbohydrate (A), protein (B) and fat (C) intake during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for macronutrient intake are mean ± standard deviation and were analysed using paired t- test. *Denotes significant difference ($p<0.05$).

Figure 3. Estimated average daily morning, afternoon and evening carbohydrate (A), protein (B) and fat (C) intake during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for macronutrient intake are mean ± standard deviation and were analysed using multiple comparisons tests. *Denotes significant difference ($p<0.05$).

Figure 4. Estimated average daily relative energy intake (A) during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA), and relative energy intake compared with expenditure (B) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for energy intake are mean ± standard deviation and were analysed using paired t- test, and intake versus expenditure analysed using repeated measures analysis of variance. *Denotes significant difference ($p<0.05$).

Figure 5. Estimated average daily morning, afternoon and evening energy intake (A) and energy

expenditure (B) during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for energy are mean ± standard deviation and were analysed using repeated measures analysis of variance. *Denotes significant difference ($p<0.05$).

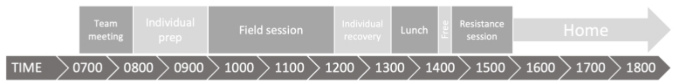

Figure 1. Schematic to show timeline of athlete daily activities

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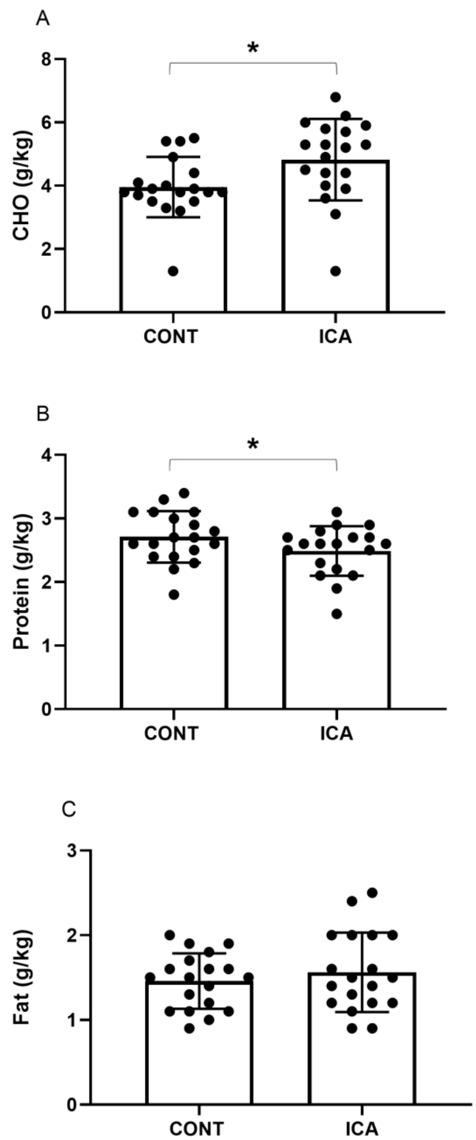

Figure 2. Estimated average daily relative carbohydrate (A), protein (B) and fat (C) intake during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for macronutrient intake are mean ± standard deviation and were analysed using paired t- test. *Denotes significant difference ($p<0.05$).

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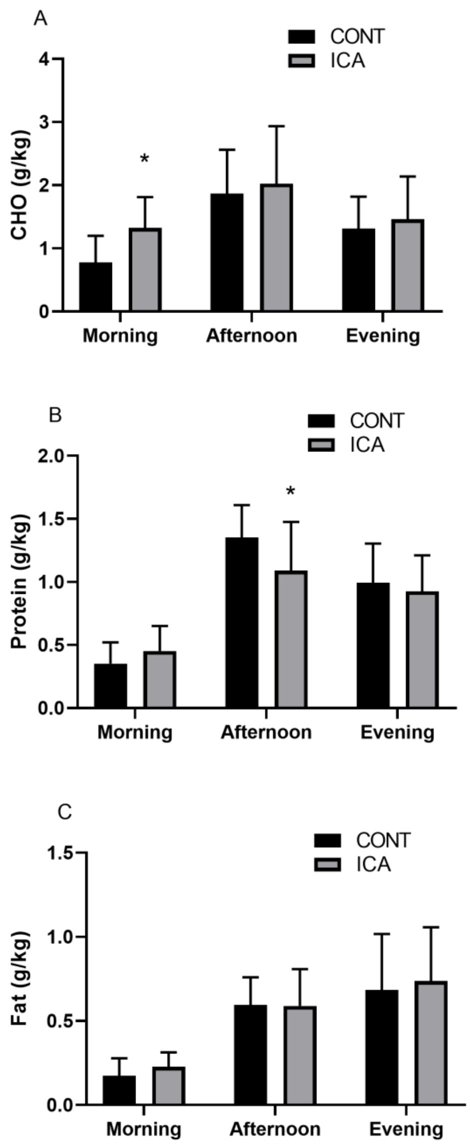

Figure 3. Estimated average daily morning, afternoon and evening carbohydrate (A), protein (B) and fat (C) intake during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for macronutrient intake are mean ± standard deviation and were analysed using multiple comparisons tests. *Denotes significant difference ($p<0.05$).

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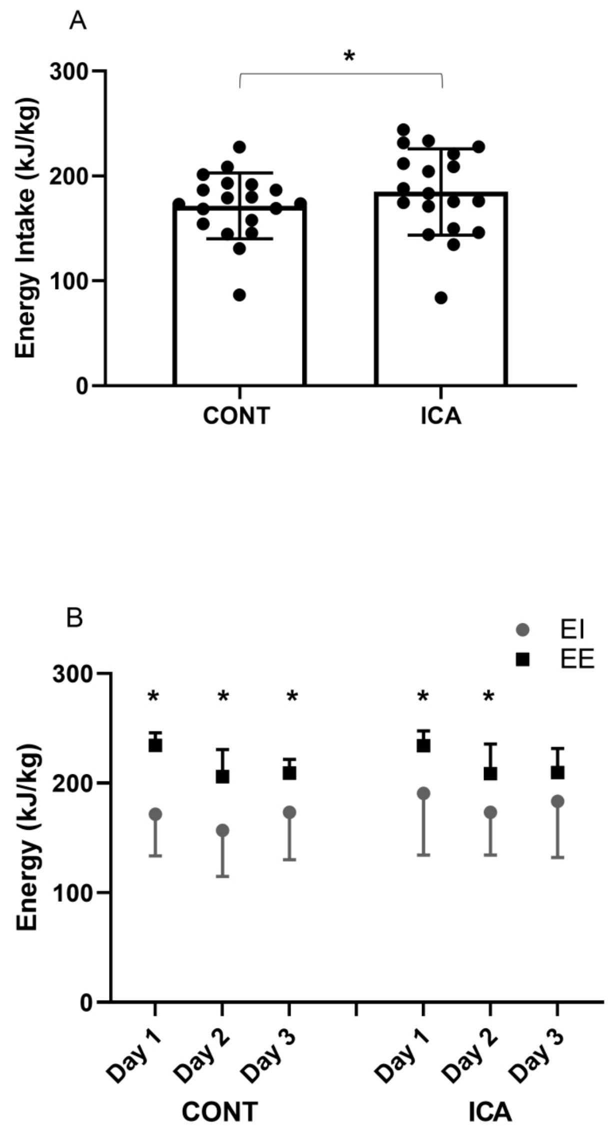

Figure 4. Estimated average daily relative energy intake (A) during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA), and relative energy intake compared with expenditure (B) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for energy intake are mean ± standard deviation and were analysed using paired t- test, and intake versus expenditure analysed using repeated measures analysis of variance. *Denotes significant difference ($p<0.05$).

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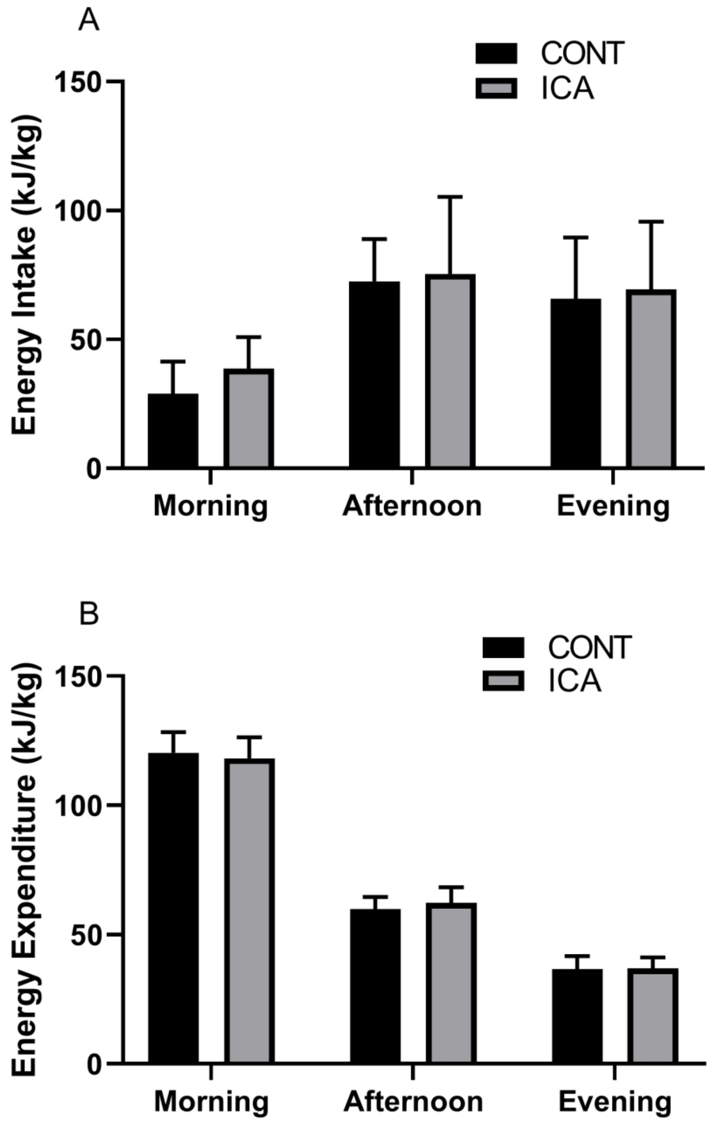

Figure 5. Estimated average daily morning, afternoon and evening energy intake (A) and energy expenditure (B) during a three-day control period of normal food availability (CONT) and a matched three-day period with increased carbohydrate availability (ICA) on high-load training days of early pre-season in elite Australian Football athletes (n=19). Data for energy are mean ± standard deviation and were analysed using repeated measures analysis of variance. *Denotes significant difference ($p<0.05$).

183x259mm (300 x 300 DPI)