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Dietary Intakes Differ by Body Composition Goals: An Observational Study of Professional Rugby Union Players in New Zealand

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Abstract

Preseason in rugby union is a period of intensive training where players undergo conditioning to prepare for the competitive season. In some cases, this includes modifying body composition through weight gain or fat loss. This study aimed to describe the macronutrient intakes of professional rugby union players during pre-season training. It was hypothesized that players required to gain weight would have a higher energy, carbohydrate and protein intake compared to those needing to lose weight. Twenty-three professional rugby players completed 3 days of dietary assessment and their sum of eight skinfolds were assessed. Players were divided into three groups by the team coaches and medical staff: weight gain, weight maintain and weight loss. Mean energy intakes were 3,875 ± 907 kcal·d^{-1} (15,965 ± 3,737 kJ·d^{-1}) (weight gain 4,532 ± 804 kcal·d^{-1}; weight maintain 3,825 ± 803 kcal·d^{-1}; weight loss 3,066 ± 407 kcal·d^{-1}) and carbohydrate intakes were 3.7 ± 1.2 g·kg^{-1}·d^{-1} (weight gain 4.8 ± 0.9 g.kg^{-1}·d^{-1}; weight maintain 2.8 ± 0.7 g·kg^{-1}·d^{-1}; weight loss 2. 6 ± 0.7 g·kg^{-1}·d^{-1}). The energy and carbohydrate intakes are similar to published intakes among rugby union players. There were significant differences in energy intake and the percent of energy from protein between the weight gain and the weight loss group.

Keywords

team sport, energy, carbohydrate, protein

Rugby union is a high-intensity intermittent team sport with players covering around 4–6 km per 80-min match (Austin et al., 2011). The pre-season for Super Rugby (the most elite competition in the Southern Hemisphere) usually lasts between 2 and 6 weeks (Argus et al., 2010). Preseason is characterized by intensive conditioning where professional players can train for up to 16 hours per week (Argus et al., 2010; Bradley et al., 2015). Players are also required to attain their optimal body composition for performance during this period. A reduction of 11 mm in the sum of eight skinfold measurements and a 2.2% increase in fat-free mass has previously been reported during 4 weeks of pre-season training among elite rugby players (Argus et al., 2010).

Understanding how players manipulate their dietary macronutrient intakes to meet their body composition goals will aid nutritionists working with athletes. The high level of training during pre-season greatly increases energy expenditure. Therefore, it is important for players to consume enough food to offset any significant energy deficit. This is especially true if the player is required to gain weight to meet their body composition goals. However, even players needing to lose weight need to ensure that this does not compromise performance. Previous research has reported that body image issues can occur in elite male rugby players (Gibson et al., 2019). Dietary intakes may not be optimal for performance if they are influenced by body image, including drive for thinness. However, no previous research has

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investigated if there is an association between body image scores and nutritional intakes.

In fact, a 2018 review highlights the lack of information on the dietary intakes of elite rugby players in general (Black et al., 2018). There are currently two published studies on the energy intakes of elite rugby players in the Northern Hemisphere and both were undertaken by Bradley, Cavanagh, Douglas, Donovan, Twist et al. (2015), Bradley, Cavanagh, Douglas, Donovan, Morton et al. (2015). One study was completed "in-season" and utilized a six-day food diary, whereas the other study was conducted during the pre-season and dietary intakes were assessed via two 24-hour diet recalls. In season energy intakes (mean ± *SD*) were 16.6 ± 1.25 MJ·d^{-1} for forwards and 15.9 ± 0.53 MJ·d^{-1} for backs (Bradley, Cavanagh, Douglas, Donovan, Twist et al., 2015). In contrast, during the pre-season, energy intake was 14.8 ± 1.9 MJ·d^{-1}, range 12.2–17.1 MJ·d^{-1} and 13.3 ± 1.9 MJ·d^{-1}, range 11.3–16.7 MJ·d^{-1} for forwards and backs, respectively (Bradley, Cavanagh, Douglas, Donovan, Morton et al., 2015). It is likely energy intakes "in-season" differ to those during pre-season due to contrasting training loads and overall goals. However, no study has investigated the effects of body composition goals on the dietary intakes of elite rugby union players.

At present no study has investigated the energy and macronutrient intakes of professional rugby players in New Zealand. In addition, these intakes have not been assessed in relation to body composition goal or body image status. The current research aimed to (1) describe the macronutrient and energy intakes of professional New Zealand rugby players and (2) to observe differences by body composition goal and body image status.

Methods

Participants

This observational cross-sectional study of elite professional rugby union players was conducted over 3-days of pre-season training. Ethical approval was obtained from the University of Otago Human (HEALTH) Ethics Committee (reference number H14/059) and complied with the Declaration of Helsinki. Participants were recruited on the first day of pre-season training. Participants were provided with information sheets and the opportunity to ask questions prior to giving informed written consent. All participants were aged over 16 years and were players for a New Zealand-based Super Rugby franchise. There were a total of 23 players (14 forwards, 9 backs). The mean ± *SD* body mass was 106.3 ± 13.3 kg and height 1.86 ± 0.07 m. Prior to the commencement of the study, coaching and support staff provided players with their individual body composition goals: weight maintenance (WM), weight gain (WG) or weight loss (WL).

Procedures

Dietary Intakes. A variety of dietary data collection techniques were employed during this study, in order to reduce participant burden. For breakfast, lunch and snacks on days 1 and 2, players selected foods provided at the training facility. This is usual practice for the team during the pre-season. Although the type of meals is dictated by the club dietitian, food and fluid intakes were ad libitum throughout the study. On Day 3, the players consumed their own breakfast and lunches, as this was a non-training day. The players were responsible for arranging their evening meals and snacks outside of training hours. The food and beverage intakes at the buffet-style team breakfasts on days 1 and 2 were recorded by researchers. Recorders were positioned at opposite ends of the food servery in order to ensure that participants and their meals could be easily identified. A member of the research team visually monitored plate waste, which was negligible for all participants on both days. For each food item available at breakfast, a standard serve was portioned out and measured on three occasions. An average weight from the three measures of each food item was calculated and used to inform data entry regarding portion size.

Snacks and drinks consumed during training and during the lunch on day 1 and 2 were recorded by the research team using checklists. Researchers were positioned at all snack stations and noted all foods selected by participants. During each training session, each participant had access to two drink bottles (one containing water and the other containing either a sugar-free or sugar-sweetened sports drink). Drink bottles were weighed before, during and after each session. This information was then used to calculate fluid, energy and carbohydrate intake during the training session.

Participants were asked to take photographs and write short descriptions, including quantities, of all food and drink they consumed away from training. Researchers recorded which participants had submitted photographs for the previous night's evening meal. Participants who had not provided the researchers with meal information were asked to carry out a dietary recall of their evening meal the following morning. Though participants occasionally mentioned habitual consumption of a food or drink, such as a cup of green tea before bed, extra information such as this was crosschecked and if appropriate, added into diet records.

Recorded dietary intakes were converted to gram and ml amounts and double-entered into Kai-culator for analysis of nutrients (Department of Human Nutrition, University of Otago, New Zealand) by two trained student dietitians. To ensure consistency, the two student dietitians had access to the same resource that contained pre-recorded photographs and weights of commonly consumed foods, which they referred to when a participant recorded a similar food item. The nutrition information panels of supplements such as protein powders were compared to similar items available in the database. If a close match was unable to be found, the nutrient content information of these products was added into the system.

Participants were also interviewed regarding their activities on a typical day away from training to help capture any unscheduled physical activity and any aspects of their dietary habits which may have been missed by the dietary assessment methods.

Energy Expenditure. Exercise energy expenditure (EEE) during training was measured by "Viper pod" units (STATSports, Newry, Northern Ireland) for on-field training sessions. The units were worn in the jersey of each player positioned between the shoulder blades. The Viper pod units sample and process global positioning system (GPS) data at 10 Hz with a built-in 100 Hz triaxial accelerometer and heart rate (HR) monitor and have previously been used to assess training load (Anderson et al., 2016). Ten-hertz frequency has previously been demonstrated to provide the most valid and reliable data for accelerations, speed and distance (Cummins et al., 2013) and has previously been used to quantify training load in research investigating rugby union players (Bradley, Cavanagh, Douglas, Donovan, Morton et al., 2015). Previous research using GPS units has reported a coefficient of variation of 4.0% in rugby league match play (Kempton et al., 2015). The accompanying computer program uses the data collected during training to estimate each participant's EE for that session, using the algorithms previously described by Osgnach et al. (2010). These algorithms have been reported to accurately assess energy expenditure from jogging and running (Brown et al., 2016).

Similarly, HR data were collected during training sessions on the Wattbikes (Wattbike Ltd, Nottingham, England), where the Polar App (Polar Electro, Kempele, Finland) was used to estimate participant EEE for that session. Previous research has reported that HR data can be used to predict energy expenditure during activity (Keytel et al., 2005). For those participants who trained but data were missing for a session (e.g. if they did not wear their Viper Pod or HR monitor during a session), the physiology team retrospectively calculated MET values for the session from a similar player. Ratings of perceived exertion (RPE data using a modified Borg scale (Borg et al., 1987) were collected following resistance training sessions to calculate an RPE (sRPE) for each individual player (Jeong et al., 2011).

Anthropometry. A Level 1 accredited International Society for the Advancement of Kinanthropometry anthropometrist measured participants' skinfolds from eight sites (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, thigh and medial calf). The sum of four skinfolds (triceps, subscapular, biceps and iliac crest) was then used to calculate body density, using equations derived by Durnin and Womersley (1974). Percentage body fat was calculated using the Siri equation (Siri, 1956) and from this estimate, fat-free mass was calculated. Skinfold measures were taken at the start, middle and end of pre-season. Body mass was measured on day 1 and day 7.

Energy Availability

From the above information, Energy availability was calculated

$$\text{Energy Availability} = (\text{Energy Intake (Kcal)} - \text{Energy Expended during Exercise (Kcal)})/\text{ Fat Free Mass (kg)}$$

Energy availability was calculated for all 3 days. The average for the two exercise days was also calculated to provide energy availability exercise.

Drive for Thinness

Players also completed the EDI-3 subscale Drive for thinness questions, which is a self-administered questionnaire, which enquires about how a participant feels about their body with six possible responses to each question "never," "rarely," "sometimes," "often," "usually" or "always" (Garner, 2004).

Statistical Analyses

Descriptive analysis yielded means, standard deviations and minimum and maximum values for each group. One-way ANOVA was used to identify differences between groups. When a significant difference was found, a post hoc pairwise comparison of means, adjusted using Bonferroni's method, was used to establish which groups were significantly different from each other. Associations were analyzed using Pearson's correlations. All statistical tests were two-tailed, and a p-value of less than .05 was used to determine statistical significance. Statistical analysis was performed using Stata 12 (StataCorp, College Station, TX).

Results

Players were excluded from the study if they did not attend training for more than 1 day of the data collection period. Thus, out of the 26 volunteers, 4 players were

Table 1. Baseline Participant Characteristics (Mean ± *SD*) for Three Training Groups: Weight Gain (WG), Weight Maintenance (WM) and Weight Loss (WL).

	WG	WM	WL	*p* value[a]
Weight (kg)	99.1 ± 14.5	109.5 ± 10.6	112.0 ± 12.1	.074
Height (cm)	185.9 ± 9.9	187.3 ± 6.7	185.3 ± 3.2	.865
Sum of 8 skinfolds (mm)	64.2 ± 14.6	71.0 ± 15.2	97.9 ± 32.5[b]	.020
Age (years)	23.4 ± 3.1	24.6 ± 1.8	23.6 ± 2.3	.549
Number of forwards	4	4	5	
Number of backs	4	4	1	

[a]Result of one-way ANOVA, if results were significantly different ($p < .05$), a post hoc analysis was used to determine nature of difference.
[b]Significantly different ($p < .05$) to WL group.

excluded due to non-study related issues, leaving a final total of 22 participants.

As reported in Table 1, the weight loss group had a significantly higher sum of eight skinfolds than both the weight maintenance and weight gain groups. Over the week, the mean weight loss for the whole squad was 0.5 ± 0.7 kg ($p = .002$).

Dietary Intakes

Energy Intake. Mean (± *SD*) energy intake for all three recording days was 3,875 ± 907 kcal·d^{-1} (15,965 ± 3,737 kJ·d^{-1}) [(day 1 = 3,986 ± 1,988 kcal·d^{-1} (16,422 ± 8,191 kJ·d^{-1}); day 2 = 4,229 ± 2,585 kcal·d^{-1} (17,424 ± 10,650 kJ.d^{-1}) and day 3 = 3,411 ± 984 kcal·d^{-1} (14,053 ± 4,054 kJ·d^{-1})]. There was a significant difference between day 2 and 3 ($p = .050$). There was no significant difference in the absolute or relative energy intake between the forwards and backs ($p = .874$). There was significantly lower energy intake in the WL group (mean ± *SD*: 3,066 ± 407 kcal·day^{-1}) compared to that of the WG group (mean ± *SD*: 4,532 ± 800 kcal·day^{-1}, $p = .001$) (Table 2). A member of the WM group had the highest mean energy intake at 5,720 kcal·day^{-1}.

Macronutrient Intakes. As can be seen in Table 2, carbohydrate contributed the largest amount of energy for each group (mean ± *SD*: 41% ± 5%), followed by fat (mean ± *SD*: 37% ± 7%) and protein (mean ± *SD*: 27% ± 4%). There were no significant differences between groups for percent energy from carbohydrate or fat ($p > .05$). Percent energy contributed by protein tended to be significantly higher for the WL group (mean ± *SD*: 22% ± 3%) compared to the WG group (mean ± *SD*: 20% ± 3%, $p = .051$). All macronutrients were significantly different relative to body mass between the weight gain and weight loss groups (all $p < .05$) (Table 2). Although there was no significant difference in total energy intake, the distribution of macronutrients was significantly different between the forwards and backs (forwards 3.4 ± 1.0 g·kg^{-1}·d^{-1} vs backs 4.6 ± 1.3 g·kg^{-1}·d^{-1}) with the forwards consuming significantly less carbohydrate ($p = .036$). A similar trend was seen for protein relative to body mass with forwards consuming 2.0 ± 0.4 g·kg^{-1}·d^{-1} and backs 2.3 ± 0.3 g·kg^{-1} ·d^{-1} ($p = .039$). Relative to total energy intake the forwards consumed a lower percent of carbohydrates ($p = .013$) and higher percent of fat ($p = .004$) than the backs.

The highest single daily carbohydrate intake was recorded on day 1 by a player in the WG group, at 7.2 g·kg^{-1}·d^{-1}, while the lowest was 0.4 g kg^{-1}·d^{-1} in a member of the WL group on day 3 (Figure 1).

Five participants had a mean protein intake below or within the recommended range described by the American College of Sports Medicine (ACSM) of 1.2–1.7 g·kg^{-1}·d^{-1} (Rodriguez et al., 2009), as presented in Figure 2. Only one member of the WG group managed to have a protein intake low enough to meet recommendations. This occurred on the rest day (day 3). The highest single daily protein intake was 4.2 g·kg^{-1}·d^{-1}, recorded by a member of the WG group on day 1.

Energy Expenditure

Scheduled Training. Players were at the training venue from 7 a.m. to 5 p.m. on days 1 and 2 and from 9 a.m. to 5 p.m. on day 3. There were 11 training sessions over the three recording days; three and a quarter hours were spent in light training, two and a half hours in moderate training and six and a quarter hours in intense training. The scheduled training sessions included rugby, recovery and activation stretching (two sessions), cardio-respiratory and strength training. Time spent at the training venue also included sitting in meetings, team breakfast and lunch.

Daily energy expenditure ranged from 2,925 to 6,038 kcal·d^{-1} (12,051–24,877 kJ·d^{-1}). Mean energy expenditure from training on day 1 was 2,949 ± 942 kcal·d^{-1} (range 1,276–4,338 kcal·d^{-1}) (12,150 ± 3,881 kJ·d^{-1}, 5,257–17,873 kJ·d^{-1}) and on day 2, it was 3,080 ± 894 kcal·d^{-1} (1,659–4,536 kcal·d^{-1}) (12,690 ± 3,683 kJ·d^{-1} 6,835–18,688 kJ·d^{-1}). Training energy expenditure was not significantly different between days, $p = .410$. There were no scheduled training sessions on day 3.

Table 2. Mean ± Standard Deviation (Range) for Energy and Macronutrient Intakes and Percent Energy Contribution From Macronutrient for Three Training Groups.

	Mean	WG	WM	WL	p value[a]
Energy (kcal·day^{-1})	3,875 ± 907 (2120–5720)	4,532 ± 804 (3221–5648)	3,825 ± 803 (3098–5720)	3,066 ± 407[b] (2549–3595)	.016
Carbohydrate					
g·kg^{-1}·d^{-1}	3.7 ± 1.2 (2.0–6.7)	4.8 ± 0.9 (3.9–6.7)	2.8 ± 0.7[b] (2.2–4.6)	2.6 ± 0.7[b] (2.0–3.7)	<.001
%TEI	41 ± 5 (29–43)	42 ± 4 (34–46)	41 ± 5 (33–48)	38 ± 6 (29–43)	. 331
Protein					
g·kg^{-1}·d^{-1}	2.1 ± 0.4 (0.8–2.9)	2.3 ± 0.4 (1.8–2.9)	1.9 ± 0.3 (1.6–2.5)	1.9 ± 0.4[b] (1.5–2.4)	.019
%TEI	23 ± 4 (16–32)	20 ± 3 (18–24)	22 ± 3 (29–28)	27 ± 4 (16–32)	.002
Fat					
g·kg^{-1}·d^{-1}	1.6 ± 0.5 (0.7–2.1)	2.0 ± 0.4 (1.6–2.8)	1.5 ± 0.3[b] (1.3–2.1)	1.2 ± 0.3[b] (0.7–1.4)	<.001
%TEI	38 ± 5 (26–46)	38 ± 4 (33–46)	37 ± 4 (30–42)	37 ± 7 (26–45)	.895

[a]Result of one-way ANOVA, if results were significantly different ($p < .05$), a post hoc analysis was used to determine the nature of difference.
[b]Significantly different from WG group.
%TEI = percentage of total energy intake; WG = weight gain; WM = weight maintain; WL = weight loss.

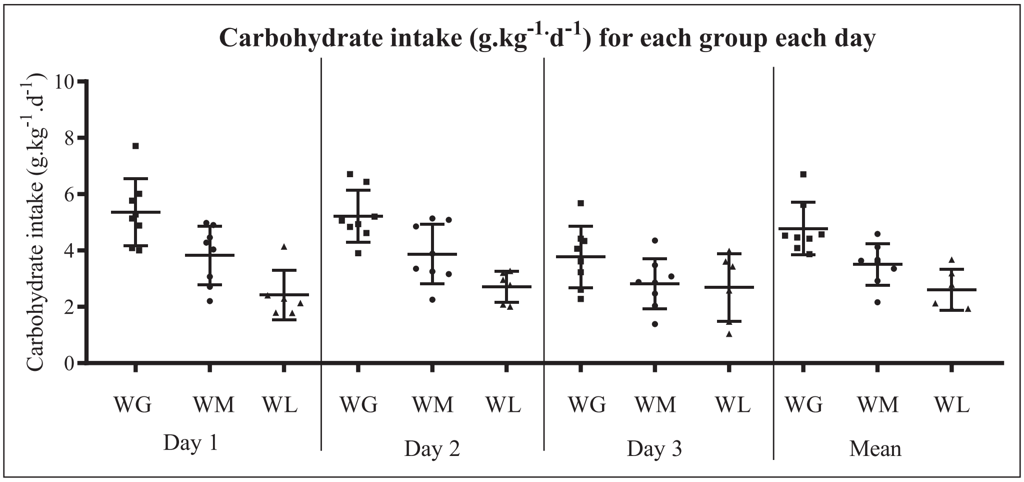

Figure 1. Carbohydrate intake ($g \cdot kg^{-1} \cdot d^{-1}$) for the weight gain (WG), weight maintenance (WM) and weight loss (WL) group each day and the mean for the 3 days for each group.
WG = weight gain; WM = weight maintain; WL = weight loss.

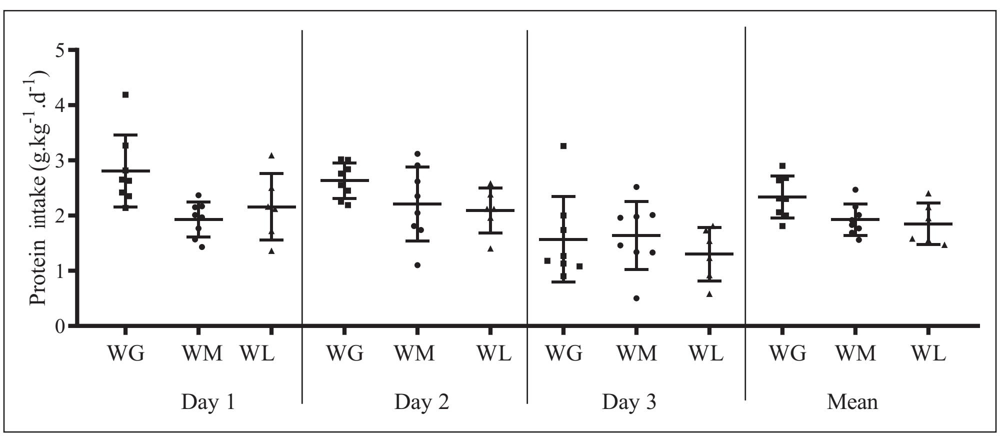

Figure 2. Protein intake ($g \cdot kg^{-1} \cdot d^{-1}$) for the weight gain (WG), weight maintenance (WM) and weight loss (WL) group each day and the mean for the 3 days for each group.
WG = weight gain; WM = weight maintain; WL = weight loss.

Activity Outside of Training. The mean energy expended outside of training was 1,080 ± 415 $kcal \cdot d^{-1}$ (4,450 ± 1,710 $kJ \cdot d^{-1}$), ranging from 393 to 1,905 kcal d^{-1} (1,619–7,849 $kJ \cdot d^{-1}$). There was a significant association between the average energy expended outside of training and the average energy intake over the study duration (p = .003, r^2 = .369). The main activities outside of training were screen time (sitting watching TV or on an iPad) and self-care activities, that is dressing and showering.

Changes in Body Composition Over Preseason

There was a decrease in mean ± *SD* sum of eight skinfolds by 7.5 ± 13.6 (range −17.7 to +1.8) mm (9.6% range 19.4% to +2.4%) over pre-season and a decrease of 4.8 ± 7.5 mm to the midpoint of pre-season, $p < .01$. The weight loss group reduced their skinfolds by 10.5 ± 5.9 mm (10.4% ± 6.1%) compared to the weight maintenance and weight gain groups who lost 4.2 ± 4.9 mm (6.7% ± 7.5%) and 8.5 ± 4.9 mm (11.9% ± 5.6%) respectively, p = .180. There was a significant association between the change in skinfolds and average energy intake (r = 0.488, p = .021), as well as for energy expenditure (r = 0.468, p = .030).

Energy Availability

Mean energy availability was 19.61 ± 11.39 $kcal \cdot kg^{-1} \cdot FFM \cdot d^{-1}$. It was higher on the rest day (28.71 ± 14.60)) compared to the two exercise days 14.64 ± 16.56

and 15.48 ± 13.32 (p = .004). There was no significant correlation between exercise EA and rest EA (p = .245, r = 0.259). There was a significant association between the two exercise days (p = .001, r = 0.669). There was a tendency for exercise EA to be lower among those with a higher drive for thinness (p = .080, r = −0.382). This was not seen on the rest day (p = .761, r = 0.069).

Discussion

This is the first study to assess the energy and macronutrient intakes of New Zealand professional rugby players. It uniquely describes the intakes in relation to body composition goals and adds to the very limited published research on dietary intakes of elite rugby union players. In line with the hypothesis, the weight gain group ingested significantly more energy than the weight loss group.

The energy intake (mean ± *SD*) for all participants across the 3 days was 3,875 ± 970 kcal·d^{-1} (15,900 ± 4,000 kJ·d^{-1}), which is similar to previously reported energy intakes of elite European rugby union players (forwards: 3,570 ± 450 kcal·d^{-1}; backs: 3,180 ± 450 kcal·d^{-1}) (Bradley, Cavanagh, Douglas, Donovan, Morton et al., 2015) and Australian rugby league players (4,230 ± 880 kcal·d^{-1}) (Lundy et al., 2006). The investigators in both of these studies speculated that the observed energy intake might have been affected by under-reporting. Despite the attempts to minimize participant burden and to monitor dietary intakes as accurately as possible, it is still possible that some underreporting may have occurred in the present study. Higher energy intakes than those observed in the current study are rarely reported in the team sports literature. For example, Baker et al. (2014) reported energy intakes of 3,522 ± 1,137 kcal·day^{-1} among 22 young (17 ± 2 years) male sports athletes (n = 22) competing in soccer, tennis, basketball, football, golf, lacrosse and baseball, Maughan (1997) reported intakes of 2,629 ± 621 kcal·day^{-1} and 3,059 ± 526 kcal·day^{-1} in two professional soccer clubs. However, there are physiological differences between soccer and rugby union that need to be considered. Rugby union players tend to be heavier and there are distinct differences between these sports regarding distance covered, duration of high intensity to rest ratios, match duration and nature of impacts (Black et al., 2018). The reported energy intakes in this study highlight the high energy demands of elite rugby union players and provide nutritionists working in this field with evidence to educate players around their energy needs. This is apparent even if they need to lose body fat to meet their body composition goals.

The current study further indicates that energy intake varies significantly depending on the body composition goals of the rugby player, highlighting the importance of dietary intakes for body composition changes and the crucial role nutritionists play in preparing athletes for competition. Those players aiming to gain muscle mass reported a higher energy intake than those wanting to lose weight, creating a slight energy deficit. This has previously resulted in a greater, albeit not significant, decrease in skinfold measurements over the pre-season in the weight loss group (Thomas et al., 2016). The 8 mm decrease in skinfolds reported in the current study is slightly smaller than the 11 mm previously reported (Argus et al., 2010). However, lack of statistical significance between the groups could be due to the large variability in the change in the sum of eight skinfolds, combined with the small sample size in each group.

The results of this study indicate that although relative protein intakes are similar to those previously reported among rugby union players (Bradley, Cavanagh, Douglas, Donovan, Morton et al., 2015; Bradley, Cavanagh, Douglas, Donovan, Twist et al., 2015), the proportion of energy from protein varies depending on body composition goals. The context is important as looking at the group as a whole; the protein intake data would suggest that protein intakes are sufficient, yet by uniquely investigating intakes by body composition goal, a different pattern emerges. For example, the WL group aimed to reduce fat mass while maintaining muscle. A review by Phillips suggested that for athletes undergoing weight loss, diets usually consist of three parts fat to one part lean tissue (Phillips, 2014). In order to preserve lean tissue during times of fat loss, protein intakes of 2.3–3.1 g·kg FFM^{-1}·d^{-1} have been suggested for lean resistance trained athletes (Helms et al., 2014). To achieve this, the WL group (mean ± *SD*: 1.7 ± 0.5·g·kg^{-1}·d^{-1}) would have to increase their protein intake. This aligns with the goals of the WG group (mean ± *SD*: 2.3 ± 0.4·g·kg^{-1}·d^{-1}), so they may also have benefited from a protein intake exceeding the recommendation. The protein intake of the WM group (mean ± *SD*: 1.9 ± 0.3·g·kg^{-1}·d^{-1}) may have prevented the loss of lean tissue as they were in an energy deficit (Tipton & Wolfe, 2004). Despite the mean protein intakes for the group being within the recommended range, when intakes were assessed by the individual player's goals, some intakes were likely sub-optimal. This highlights the importance of the team sports nutritionists to ensure factors such as body composition goals are taken into account when providing dietary information.

The current study, like previous studies from the Northern Hemisphere, observed carbohydrate intakes below those recommended by Thomas et al. (2016), who suggest a carbohydrate intake of 5–7 g·kg^{-1}·d^{-1} during the competitive season and higher intakes in pre-season. The reported overall intakes for carbohydrate were similar to those reported by Bradley, Cavanagh, Douglas, Donovan, Morton, et al. (2015) (3.3 ± 0.7 g·kg^{-1}·d^{-1} and 4.1 ± 0.4 g·kg^{-1}·d^{-1} for forwards and backs, respectively, compared to 3.7 ± 1.2 $g \cdot kg^{-1} \cdot d^{-1}$ in the present study). Only one participant had a mean carbohydrate intake over the 3 days, which fell within the recommended range. Further, these results, though considered low compared to recommendations (Thomas et al., 2016), are similar to carbohydrate intakes reported in athletes from a range of sports (Cole et al., 2005; Drenowatz et al., 2012; Kirwan et al., 2012; Maughan, 1997). Bradley, Cavanagh, Douglas, Donovan, Morton et al. (2015) suggested the carbohydrate intakes they observed in elite rugby union players may have been appropriate due to the low levels of exercise energy expenditure in their study (total weekly running distance was 9.8 km for forwards and 11.6 km for backs). Few studies have investigated the carbohydrate needs of rugby players. Bradley et al. (2016) compared diets 3 $g \cdot kg^{-1} \cdot d^{-1}$ or 6 $g \cdot kg^{-1} \cdot d^{-1}$ of carbohydrate in rugby league players (Bradley et al., 2016). They reported no differences in movement patterns or pre-match glycogen concentrations between the two diets. However, it must be noted that the results may have been influenced by the study protocol which included a sufficient carbohydrate intake by all the players in the days leading up to the study.

Despite the low overall carbohydrate intake, it appears that the proportion of carbohydrate in the diet was unaffected by body composition goals, which would suggest that the weight loss group were not specifically following a low carbohydrate diet for weight loss purposes. Although below-recommended levels, players were still ingesting 287 g of carbohydrate which would not be classed as a low carbohydrate diet. Previous research suggests that low carbohydrate diets include a ketogenic diet (<20 g day^{-1} CHO), high fat (80% of energy) diet (Phinney et al., 1983) or a slightly lower high fat (60–65% of energy) diet (Goedecke et al., 1999; Lambert et al., 1994). None of the players in the present study had such a low intake of carbohydrates.

Bradley, Cavanagh, Douglas, Donovan, Twist et al. (2015) reported a training energy expenditure of 14.2 ± 1.2 MJ and 14.0 ± 0.5 MJ for forwards and backs, respectively, calculated from accelerometry. Smith et al. (2018) reported that total daily energy expenditure was 4,414 ± 688 $kcal \cdot d^{-1}$ (~18.5 $MJ \cdot d^{-1}$) and 4,761 ± 1,523 $kcal \cdot d^{-1}$ (~19.9 MJ) in elite under 20 and under 24 players (Smith et al., 2018). Although the observed EEE in the current study was lower (mean ± *SD*: 8,277 ± 2,179 $kJ \cdot d^{-1}$) than previously reported, this does include one recovery day. The exercise energy expended during the 2 days of "full" training was 12,150 ± 3,881 kJ for day 1 and 12,690 ± 3,683 kJ for day 2, which is similar to those reported by Bradley, Cavanagh, Douglas, Donovan, Twist et al. (2015) but lower than Smith et al. (2018) who used doubly labeled water. Interestingly, there was a large difference in EEE on day 3 compared to days 1 and 2, but only a small decrease in energy intake on day 3. This highlights the importance of rest days to restore energy balance during the pre-season.

Limitations

The data from the present study provide valuable insight into the nutritional intakes of elite rugby union players in New Zealand. Future research should build on this study to incorporate performance and health measures over the course of the pre-season and during the season. The energy intakes and expenditures in the current study suggest that players may be putting themselves at risk of low energy availability, and although the full consequences of this are unknown, it should be further investigated in this population (Williams et al., 2019). Although measures were taken to increase accuracy, measuring dietary intakes is prone to under-reporting and changing of dietary habits (Gibson, 2005). Further, only 3 days of dietary intake were recorded and therefore, changes over the course of pre-season will not have been identified. Future research should include more time points to track changes in dietary intake performance and body composition.

This is the first study to report the energy intakes of professional Super Rugby players during pre-season training and uniquely reports that energy intakes and the proportion of energy from protein differ depending on body composition goals. Further, this study demonstrates that the energy, carbohydrate and protein intakes were similar between New Zealand and published research in the Northern Hemisphere. The carbohydrate intakes which are lower than currently recommended suggest that the establishment of optimal carbohydrate intakes for professional rugby players potentially requires further investigation.

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