Dietary Intakes, Nutrition Knowledge and the Factors Influencing Dietary Behaviours and Food Choices of Professional Australian Football Athletes

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This PhD was completed as a part of an industry-based partnership between La Trobe University and Carlton Football club.

Statement of Authorship

This thesis includes work by the author that has been published or accepted for publication as described in the text. Except where reference is made in the text of the thesis, this thesis contains no other material published elsewhere or extracted in whole or in part from a thesis accepted for the award of any other degree or diploma. No other person's work has been used without due acknowledgment in the main text of the thesis. This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution. This work was supported by an Australian Government Research Training Program Scholarship

I also certify that the thesis has been written by me, Sarah Louise Jenner. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged.

Sarah Jenner

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CHAPTER FOUR

Jenner, S.L., Trakman, G., Coutts, A., Kempton, T., Ryan, S., Forsyth, A., and Belski, R. (2018). Dietary Intake of Professional Australian Football Athletes Surrounding Body Composition Assessment. *Journal of the International Society of Sports Nutrition.* 2018;15(1):43. doi:10.1186/s12970-018-0248-5.

CHAPTER FIVE

Jenner, S.L., Devlin, B., Forsyth, A., & Belski, R. (2019). Dietary intakes of Professional Australian Football League Women's (AFLW) Athletes During a Preseason Training Week.. *Journal of Science and Medicine in Sport.* 2019;22(11):1266-1271. doi:10.1016/j.jsams.2019.06.014.

Jenner S.L, Devlin B., Forsyth A., Belski R. (2020). Assessing the Nutrition Knowledge of Professional Female Australian Football (AFLW) athletes. *Journal of Science and Medicine in Football*. 2020:1-6. doi.org/10.1080/24733938.2020.1752929

Publications (prepared for submission)

CHAPTER SIX

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Publications (Co-author)

Trakman G.L., Forsyth A., Middleton K., Hoye R, **Jenner, S.**, Keenan S. and Belski, R. (2018). Australian Football Athletes Lack Awareness of Current Sport Nutrition Guidelines. *International Journal of Sport Nutrition and Exercise Metabolism.* 2018:1.

List of Conference and Seminar Presentations

Conference and Seminar presentations

Oral presentations

Nutrition Cooking Programs- Do they Improve Professional Athletes' Dietary Intakes? *Sports Dietitian Australia Conference – Propelling your Knowledge and Practice.* Melbourne, Australia, October 2017.

Exploring the Effectiveness of Different Methods of Nutrition Education on Nutrition Knowledge in Australian Football Women's (AFLW). *Nutrition for Sport, Exercise and Performance: book launch and expert seminar*. Melbourne, Australia, February 2019.

Assessing the Dietary Intakes of Female Australian Football (AFLW) Athletes. *World Congress of Science and Football conference*. Melbourne, Australia, June 2019.

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Poster Presentations

Dietary Intakes of Professional and Semi-Professional Team Sport Athletes Do Not Meet Sport Nutrition Recommendations—A Systematic Literature Review. *World Congress of Science and Football conference*. Melbourne, Australia, June 2019.

Statement of Candidate Contribution

Table A. Percentage contribution (%) of authors to peer reviewed manuscripts

CHAPTER THREE

Study 3.2	**Research Design**	**Data Collection**	**Data Analysis**	**Manuscript Preparation**	**Manuscript Revision**
Jenner, Sarah	70%	100%	60%	100%	
Buckley, Georgia			40%		
Belski, Regina	10%				20%
Devlin, Brooke	10%				20%
Forsyth, Adrienne	10%				60%

CHAPTER FOUR

Study 4.2	**Research Design**	**Data Collection**	**Data Analysis**	**Manuscript Preparation**	**Manuscript Revision**
Jenner, Sarah	60%	100%	80%	100%	
Trakman, Gina					2.5%
Coutts, Aaron	10%				10%
Kempton, Thomas	10%				5%
Ryan, Sam					2.5%
Forsyth, Adrienne			10%		10%
Belski, Regina	20%		10%		70%

CHAPTER FIVE

Study 5.2	**Research Design**	**Data Collection**	**Data Analysis**	**Manuscript Preparation**	**Manuscript Revision**
Jenner, Sarah	60%	100%	90%	100%	
Forsyth, Adrienne			10%		40%
Devlin, Brooke					30%
Belski, Regina	40%				30%

Study 5.3	Research Design	Data Collection	Data Analysis	Manuscript Preparation	Manuscript Revision
Jenner, Sarah	60%	100%	90%	100%	
Forsyth, Adrienne			10%		40%
Devlin, Brooke					30%
Belski, Regina	40%				30%

CHAPTER SIX

Study 6.2	Research Design	Data Collection	Data Analysis	Manuscript Preparation	Manuscript Revision
Jenner, Sarah	60%	100%	70%	100%	
Belski, Regina	10%				10%
Devlin, Brooke					10%
Forsyth, Adrienne	30%		30%		80%

Abstract

Optimising an athlete's dietary intake can help to maximise training adaptations, support recovery and enhance physical performance. Nutrition is also important for athletic performance and can support an athlete's short and long-term health and wellbeing. Australian football (AF) is a high-intensity and intermittent team sport, that incorporates a range of unique physical traits such as agility, strength and power. Because of this, athletes competing in AF have unique nutrition requirements in order to meet the demands of training and competition. Sports nutrition professionals such as Sports Dietitians (SDs), play a major role in supporting athletes to meet their nutrition related goals. All professional AF clubs in Australia employ SDs, however athletes' access to nutrition advice will vary, depending on the nature of the role within the team environment. As a part of an industry-based partnership, this PhD project aimed to provide an assessment of the nutrition knowledge (NK) and dietary intakes of professional AF athletes from one professional AF club to identify gaps requiring nutrition intervention and to explore factors influencing male AF athletes' dietary behaviours and food choices.

The dietary intakes and nutrition knowledge of professional AF athletes competing in the Australian Football League (i.e. AFL) and Australian Football League Women's (AFLW) were assessed using self-reported food records and a validated nutrition knowledge questionnaire (i.e. Nutrition for Sport Knowledge Questionnaire (NSKQ)). Dietary intakes were assessed across a training week and compared against training loads observed. Food records were analysed using a food composition database (Foodworks Version 8, Xyris, Queensland) and nutrition knowledge was assessed according to the NSKQ protocols. A statistical analysis of dietary intake and NK was conducted using IBM SPSS Statistics (Windows version 24.0). A Pearson's coefficient was used to explore associations between dietary intake and NK and demographics such as age, experience level and education. Semi-structured interviews were conducted with male AF athletes to explore factors influencing food choice. The barriers and the motivators behind food choice and were analysed thematically.

The main findings of the research include that professional AF athletes' (i.e. male and female) dietary intakes did not align with gender-specific energy (i.e. AFL: 2177 ± 430 $kcal \cdot kg^{-1} \cdot day^{-1}$ and AFLW: 1884 ± 457 $kcal \cdot kg^{-1} \cdot day^{-1}$) and/or CHO (i.e. AFL: 2.4 ± $g \cdot kg^{-1} \cdot day^{-1}$ and AFLW: 2.7 ± 0.7 $g \cdot kg^{-1} \cdot day^{-1}$) recommendations advocated by the International Society of Sports Nutrition. No significant differences ($P>0.05$) were found when dietary intakes were assessed across a preseason training week and on average male AF athletes reported greater CHO intakes on light training days, when compared to main training and recovery days. The NSKQ results reveals that AF athletes were found to have poor to average NK, with a range of knowledge gaps in sports nutrition, micro-nutrients and supplements identified. The qualitative interviews highlighted a range of individual factors which influence male AF athletes' food choice. Specifically, younger and inexperienced athletes perceived pressures surrounding body composition as a barrier to meeting nutrition goals. In comparison, experienced athletes perceived the need to optimise dietary intake for performance and recovery outcomes, not just body composition. Collectively, male and female AF athletes preferred an individualised approach to nutrition, provided by one-on-one consultations with sports nutrition professionals such as SDs.

The findings of this research highlight that AF athletes may benefit from greater access to individualised nutrition advice that is tailored according to their goals and training and competition demands. Younger and inexperienced athletes may benefit from greater nutrition education regarding the link between nutrition and performance. Furthermore, sports nutrition professionals may see benefit in the inclusion of experienced athletes in nutrition education and messaging provided to younger and inexperienced athletes, to promote supportive cultures surrounding dietary intake. It is evident, from the findings that a multi-disciplinary approach is required when developing body composition goals, to ensure individual athlete needs are considered and that rigid targets advocated for teams are avoided. Furthermore, the development of sports specific body composition ranges, especially in AF, may be useful to inform evidence-based practice. Additionally, research is required, to assess the efficacy of nutrition education strategies that promote an individualised approach.

Glossary of Abbreviations

AccSD	Accredited Sports Dietitian *(Note: Sports nutrition professional used in thesis)*
AIS	Australian Institute of Sport
ACSM	American College of Sports Medicine
ADA	American Dietetic Association
AF	Australian Football
AFL	Australian Football League
AFLW	Australian Football League Women's
ARU	Australian Rugby Union
ASADA	Australian Sports Anti-doping Authority
BMR	Basal Metabolic Rate
BHI	Beverage Hydration Index
BIA	Bioelectrical Impedance Analysis
BF	Body fat
BMC	Bone Mineral Content
CHO	Carbohydrate
CINAHL	Cumulative Index of Nursing and Allied Health Literature
DI	Dietary Intake
DRV	Dietary Reference Values
DXA	Duel-energy X-ray Absorptiometry
EA	Energy Availability
EAAs	Essential Amino Acids
EAR	Estimated Average Requirements
EEI	Estimated Energy Intake
FIFA	International Federation of Association Football
FFSTM	Fat Free Soft Tissue Mass
FFQ	Food Frequency Questionnaire
FM	Fat Mass
G	Gram
GE	Gastric Emptying
GIT	Gastrointestinal
GNKQ	General Nutrition Knowledge Questionnaire
GPS	Global Positioning System
GLP-1	Glucagon-like Peptide-1
HSL	Hormone Sensitive Lipase
IOC	International Olympic Committee
ISAK	International Society for the Advancement of Kinanthropometry
ISSN	International Society of Sports Nutrition
Kg	Kilogram
kJ	Kilojoule
LEA	Low energy availability
LCHF	Low Carbohydrate, High Fat
MEDLINE	Medlars International Literature Online
mg	Milligram
MJ	Megajoule
NRV	National Reference Values
NEAFL	North East Australian Football League
NK	Nutrition Knowledge
NSKQ	Nutrition for Sport Knowledge Questionnaire
ORS	Oral Rehydration Solutions
PICOS	Participant, Intervention, Comparison, Outcome and Study Design
PRISMA	Preferred Reporting Items for Systematic Review
RCT	Randomised Control Trial

RDA	Recommended Dietary Allowances
RDI	Recommended Dietary Intakes
RED-S	Relative Energy Deficiency Syndrome
SAFL	South Australian Football League
SDs	Sports Dietitians
SD	Standard Deviation
SF	Skinfolds
SLR	Systematic Literature Review
VFL	Victorian Football League
WAFL	Western Australia Football League
WADA	World Anti-doping Authority
WOS	Web of Science
YRS	Years

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CHAPTER ONE

1.1 Context and Rationale

An individualised approach is integral to provide nutrition advice that is tailored to an athlete's needs; however, providing individualised advice within team sport environments can be resource intensive. Many team sport environments still view nutrition as a non-essential service which poses challenges for sports nutrition professionals when providing nutrition intervention. Team sport athletes including those competing in AF, have been found to report DIs that do not align with energy and carbohydrate (CHO) recommendations (1-3). There is a need for nutrition intervention and research to assess why team sport athletes do not meet sports nutrition recommendations. To date, no research has explored in combination the dietary and behavioural patterns of professional AF athletes and identified factors that influence their food choice which may impact their ability to meet sport nutrition recommendations. Furthermore, no research has assessed the DIs of professional female AF athletes, due to the relatively new nature of the professional female AF league (i.e. Australian Football League Women's (AFLW)).

As a part of an industry based partnership, I was embedded within one professional AF club, to combine research with the provision of nutrition related services. Prior to this appointment, nutrition had been perceived by the AF club as a 'nice to have service' with access to a sports nutrition professional limited to 6 hours per week. In addition AF athletes' had no access to a team kitchen, training based foods and snacks and had minimal nutrition education opportunities. As a result, AF athletes sought nutrition advice from a range of sources including teammates, coaches and other high performance staff.

Therefore, this research aimed to assess the DI and NK of professional AF athletes and explore factors that influence athletes' food choice. Understanding the drivers and barriers behind food choice provides valuable information for sports nutrition professionals to ensure intent translates into practice and to support behaviour change. Furthermore, assessing the DI and NK of athletes can help to identify gaps requiring nutrition intervention.

1.2 Study Aims

The primary aims of research studies included in this PhD project include to provide an assessment of the DI and NK of professional male and female AF athletes and to explore factors influencing male AF athletes' dietary behaviours and food choice (Figure 1).

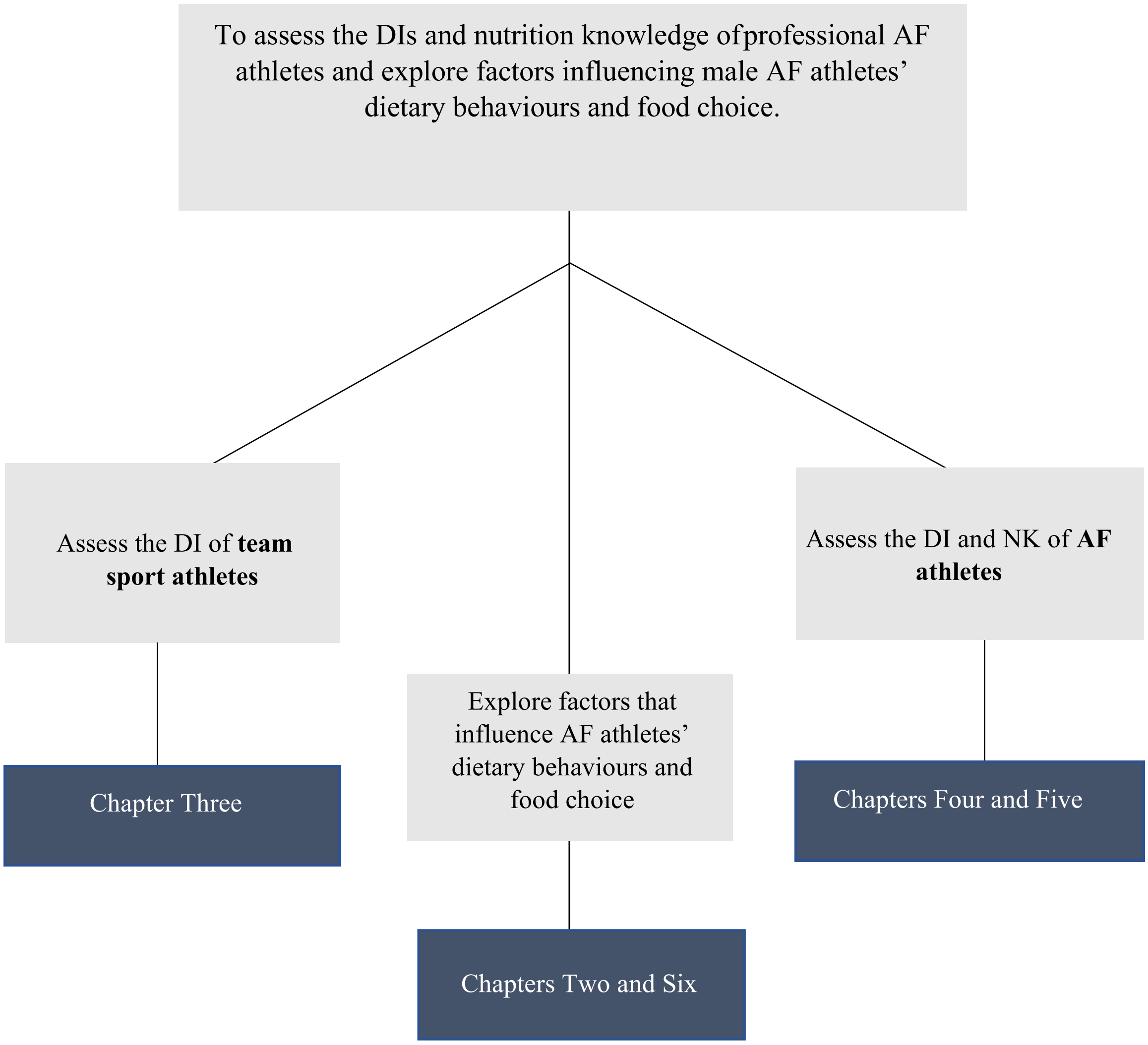

Figure 1. Summary of PhD research aims

1.3 Hypotheses

Given nutrition services were previously limited within the AF club and based on existing literature (2, 3), it was hypothesised that AF athletes DIs would be suboptimal and would not align with current sports nutrition recommendations. The below hypotheses were established from observations whilst undertaking dietetic intervention within the AF club environment.

1. Male AF athletes will have DIs that do not align with sports nutrition recommendations as measured by food records and compared against sports nutrition recommendations advocated by the ISSN.

2. Female AF athletes will have DIs that do not align with sports nutrition recommendations for energy, CHO and population guidelines for iron and calcium intakes as measured by food records and compared against sports nutrition recommendations by the ISSN and population guidelines such as Recommended dietary intakes (RDI).

3. Male AF athletes will have poor NK as measured by using a validated NK questionnaire (i.e. NSKQ) and comparable to NK assessed in previous research with professional male AF athletes.

4. Female AF athletes will have poor NK as measured by using a validated NK questionnaire (i.e. NSKQ) and comparable to NK assessed in previous research with semi-professional female AF athletes.

5. Male AF athletes will manipulate their DI and food choices prior to a body composition assessment (i.e. Dual energy x-ray absorptiometry (DXA) scan).

1.4. Overview and Research Objectives

Factors such as NK, body composition and social relationships (i.e. peers, family) can influence dietary and behavioural practices of professional athletes (4). To what extent these factors influence athletes meeting their nutrition goals, is currently unknown. Research studies included in this PhD will provide an assessment of the DI and NK of professional male and female AF athletes and will examine factors that influence male AF athletes meeting their nutrition goals (Figure 1). Research included will intend to identify gaps requiring nutrition intervention and provide an insight into the decision-making behind food choice. It is hoped that new knowledge gained would help to provide tailored nutrition services that best meet the needs and preferences of the athletes within the AF club and can be generalised to other AF and professional team sport environments.

Study 1: *Dietary Intakes of Professional and Semi-Professional Team Sport Athletes do not meet Sport Nutrition Recommendations—A Systematic Literature Review*

Aims: To systematically review the literature assessing the DIs of professional and semi-professional team sport athletes and to identify priority areas for nutrition intervention.

Hypothesis: It was hypothesized that DIs of professional and semi-professional team sport athletes would not align with sports nutrition recommendations for energy and CHO, which aligns with a previous review that assessed team sport athletes' dietary intakes' (1).

Significance: Due to the vast amount of research that has been undertaken in the past decade in professional and semi-professional team sport, this systematic review will provide an update to the 2011 review by Holway and Spriet (1). Furthermore, this review will intend to identify gaps requiring nutrition intervention and provide an insight for sports nutrition professionals working within team sport environments.

Study 2: *Assessing the Dietary Intake and Nutrition Knowledge of Professional Australian Football Athletes (Chapter 3)*

Aims: To assess the DI and the NK of professional male AF athletes to identify gaps requiring nutrition intervention. Secondary aims include the examination of DIs across a preseason training week comparing intakes against training loads.

Hypothesis: Due to athletes' previous limited access to individualised nutrition advice, it was hypothesized professional male AF athletes were likely to report DIs that were suboptimal and would not align with sports nutrition recommendations. Furthermore, it was hypothesised that athletes would have poor NK, due to previously limited access to a sports nutrition professional.

Significance: Research that provides an assessment of professional AF athletes' DIs across a training week is limited. Due to the increasing relevance of dietary manipulation strategies to promote training adaptations and their growing use within team sport, research that provides an insight into whether AF athletes habitually meet these guidelines, is warranted. Furthermore, this study will intend to identify gaps requiring possible nutrition intervention and will aim to improve AF athletes' access to individualised nutrition advice.

Study 3: *Assessing the Dietary Intakes of Professional Female Australian Football Athletes (Chapter 4)*

Aims: To assess the DIs of professional female AF athletes, across a preseason training week and compare intakes against general population-based guidelines such as the Nutrient Reference Values (NRVs) and Australian Guide to Healthy Eating (AGHE) and sports nutrition recommendations advocated by the ISSN. The secondary aim of this study was to examine DIs across a preseason training week and to highlight areas requiring nutrition intervention.

Hypothesis: It was hypothesized that professional female athletes were likely to report energy, CHO, iron and calcium intakes that do not align with recommendations, which has been found by previous research undertaken with semi-professional female AF athletes (5).

Significance: This study will provide the first assessment of professional female AF athletes' DIs. To date, no research has compared female AF athletes' DIs against training loads (i.e. Global Positioning System (GPS)) observed across a training week. Due to the relatively new nature of the professional female AF league baseline DI data, will be valuable for sports nutrition professionals and scientists working within these environments. This research will hope to provide evidence on the type of nutrition intervention required within AFLW environments (i.e. nutrition education, individualised advice).

Study 4: *Assessing the Nutrition Knowledge of Professional Female Australian Football Athletes (Chapter 4)*

Aims: To assess the NK of professional female AF athletes to identify gaps and to help tailor future nutrition interventions.

Hypothesis: It was hypothesized that the NK of professional female AF athletes would be average, as athletes' access to nutrition education was limited and previous research had identified semi-professional female AF athletes report average NK.

Significance: This study will provide the first assessment of professional female AF athletes' NK. As access to a sports nutrition professional is limited within AFLW environments, this study hopes to provide an insight into NK gaps and can be used to tailor nutrition advice and education provided to female AF athletes.

Study 5: *A Qualitative Investigation of Factors Influencing the Dietary Intakes of Professional Australian Football Players.*

Aims: To explore the factors that influence the dietary habits and food choice of professional male AF athletes. A secondary aim was to explore dietary behaviours in the days and weeks prior to a body composition assessment (i.e. DXA scan).

Hypothesis: It was hypothesized that pressures to meet body composition goals were a perceived barrier for male AF athletes to meeting their nutrition goals. Due to the assumed influence of meeting body composition goals, it was hypothesized AF athletes may adjust their DIs, specifically CHO, prior to a DXA scan.

Significance: No research has explored factors that influence male AF athletes' dietary habits and food choice, particularly surrounding a body composition assessment. This study in combination with DI data collected in Chapter 3, will provide valuable insight into factors that may act as barriers to consuming adequate DIs for athletes and intends to be used as a guide on how sports nutrition professionals can best support athletes meeting their nutrition goals.

References

1. Holway F, Spriet L. Sport-specific nutrition: Practical strategies for team sports. Journal of Sports Sciences. 2011;(29): 25-115.
2. Devlin B, Leveritt M, Kingsley M, Belski R. Dietary Intake, Body Composition, and Nutrition Knowledge of Australian Football and Soccer Players: Implications for Sports Nutrition Professionals in Practice. International Journal of Sport Nutrition and Exercise Metabolism. 2016;27(2):8-130.
3. Bilsborough J, Greenway K, Livingston S, Cordy J, Coutts A. Changes in Anthropometry, Upper-Body Strength, and Nutrient Intake in Professional Australian Football Players During a Season. International Journal of Sports Physiology and Performance. 2016;11(3):290-300.
4. Birkenhead K, Slater G. A Review of Factors Influencing Athletes' Food Choices. Sports Medicine. 2015;(45):1511-1522.
5. Condo D, Lohman R, Kelly M, Carr A. Nutritional Intake, Sports Nutrition Knowledge and Energy Availability in Female Australian Rules Football Players. Nutrients. 2019;11(5):971.

2.1. Australian Football: A Background and Summary of the Physical Demands

2.1.1 Australian Football

AF originated in 1858 and is a popular sporting code played by individuals in Australia and throughout 30 countries across the world (1, 2). AF is recognisable by its large oval playing surface (Figure 2) and match-play that includes intermittent high-intensity periods of play, interspersed with periods of recovery (3). Power, agility, speed and endurance are important physical characteristics of AF athletes and are essential to meet match-play demands (1, 2). AF match-play consists of two teams of 22 players each, with 18 on field and four on the interchange bench. Athletes are required to maintain possession of the football, using a combination of kicking and handballing amongst their team, to advance their position in the field closer to the goals and to kick

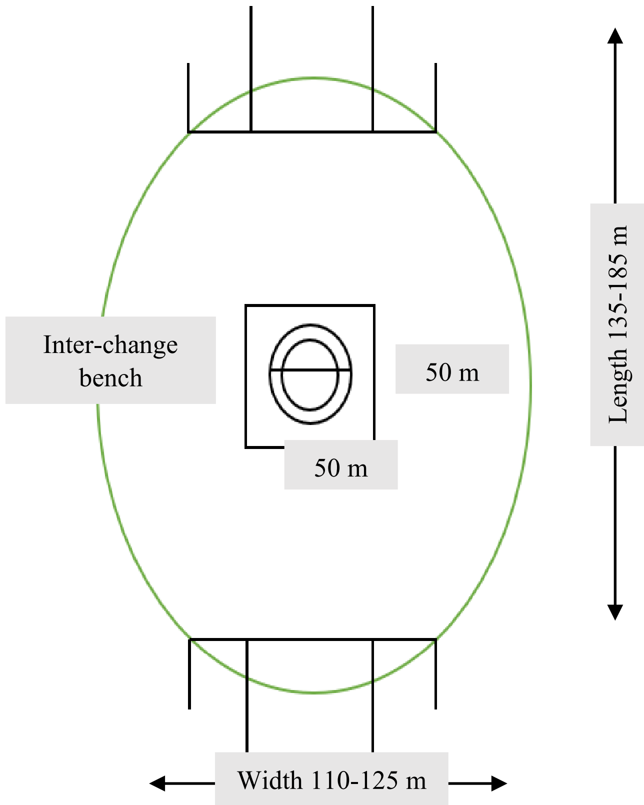

Figure 2. AF field dimensions and size

Figure above adapted from Figure 1. presented by Johnson et al. (2018) (2)

for either 6 points (through the middle two posts) or for one point (through the two outer posts). As needed, the interchange bench will allow constant rotation of athletes onto and off the field. At a professional level (i.e. AFL) rotations cannot exceed 90 rotations per match (2, 4).

Total match-play is divided into four 20 minute quarters with time added to the end of each quarter to take into consideration stoppages played (i.e. total playing time approximately 120 minutes) (2). On average, research in professional AF has found athletes cover approximately 11.0-13.5km of total distance per match (2). Athletes are provided with breaks throughout the match, which consists of two six-minute breaks at quarter and three-quarter time and a 20-minute rest period during the half time break. These breaks act as an opportunity for athletes to work with coaches regarding match tactics and additionally allow athletes to rehydrate and consume nutrients as per individual needs (4). Due to the limited time provided during these breaks, fast acting CHO sources may be provided if prior fuelling is not adequate (e.g. High glycaemic index (High GI) CHO such as gels, lollies, fruit etc.)) and fluids such as sports drink, oral rehydration solutions (ORS) and water, are recommended.

2.1.2. Professional and semi-professional AF leagues

The professional AF competitions include the AFL and AFLW. The reserve AF league which is classed as semi-professional includes the Victorian Football League (VFL), South Australian Football League (SAFL), Western Australia Football League (WAFL) and North East Australian Football League (NEAFL). Furthermore, teams included in the reserve league can be classified as an a) VFL/AFL affiliated club, b) stand-alone AFL reserve team OR c) stand-alone VFL senior teams. The AF reserve system accommodates for a mix of AFL-listed players and unlisted semi-professional AF athletes. Taken together, the AFL, AFLW and reserve leagues allow Australian and international athletes the opportunity to compete in AF professionally and semi-professionally and depending on the league will train on a part-time (i.e. AFLW and reserve leagues) or full-time basis (i.e. AFL).

2.1.2.1. AFL

The AFL is the most popular sporting code in Australia, drawing the largest television audiences and public support in comparison to any other sport played in Australia (3). Twelve of the 18 teams competing in the AFL train within the southern state of Victoria (Table 1). The AFL competition season is made up of 23 home and away matches, with additional matches played for finals at the end of the season. The AFL competition includes teams from across Australia including Victoria, New South Wales, South Australia, Western Australia and Queensland (Table 1).

Table 1. All teams competing in the AFL competition

AFL (n=18)				
Victoria	**South Australia**	**Western Australia**	**New South Wales**	**Queensland**
Western Bulldogs FC Carlton FC Collingwood FC Richmond FC St Kilda FC Melbourne FC North Melbourne FC Hawthorn FC Essendon FC Geelong FC	Adelaide FC Port Adelaide FC	Freemantle FC West Coast Eagles FC	Greater Westerns Sydney Giants FC Sydney Swans FC	Brisbane Lions FC Gold Coast Suns FC

Abbreviations: Football Club; FC

2.1.2.2. AFLW

In 2016, the AFLW was established and in the first season eight teams competed across a seven-game home and away season (5). This league continues to grow and engage interest from other AFL clubs and their supporters and in the most recent 2020 season an additional four teams joined the professional league (Table 2). The physical and match day demands of AFLW athletes are vastly different to that of AFL athletes (5). In comparison to the AFL, the AFLW has a significantly shortened preseason (~3months) and competition season (~2 months) (5). Furthermore, match-play is shortened with AFLW games consisting of 4 x 15-minute quarters (5).

Due to the recent establishment of this league, very little research has assessed the physical characteristics of these athletes, as well as explore their nutrition needs. AFLW athletes currently compete and train on a part-time basis, with many also working and/or studying. As a result of these circumstances female AF athletes will have unique training and nutrition needs. Therefore, it is important research is undertaken to assess AFLW athletes' physical characteristics, training and performance capacities in order to better understand how best to support performance and recovery needs.

Table 2. All teams competing in the 2020 AFLW competition

AFLW as of 2020 (n=14)				
Victoria	**South Australia**	**Western Australia**	**New South Wales**	**Queensland**
Western Bulldogs FC Carlton FC Collingwood FC Richmond FC St Kilda FC Melbourne FC North Melbourne FC Geelong FC	Adelaide FC	Freemantle FC West Coast Eagles FC	Greater Westerns Sydney Giants FC	Brisbane Lions FC Gold Coast Suns FC

Abbreviations: Football Club; FC

2.1.3. Physical demands of AF

As stated, AF relies on a variety of physical attributes including speed, agility, power and aerobic fitness (2). Because of this, athletes must have well-developed aerobic capacities, in order to keep up with the duration and intermittent demands of AF training and match-play (2). The AFL season is characterised by two macro seasons which includes a) preseason (~4 months) and b) competition season (~6 months). The focus of training loads and the intensities at which athletes compete, will differ between these macro seasons (6).

Physical preparation undertaken during the preseason phase, will focus on the development of aerobic fitness and the ability to compete under fatigue, which will use both the aerobic and anerobic energy systems (2). Aerobic fitness is important for athletic performance and in the prevention of injury, especially for developing youth athletes (7). Most of the training loads performed during the preseason phase is made up of skills, conditioning and running blocks (6). Total distance covered during a preseason training week has been reported as approximately 20 km or 2700 Arbitrary units (AU)), which is greater than loads performed during the competition phase (2, 6). Training loads (AU) performed during the preseason phase can be made up of skills, running, other conditioning training (i.e. cross training, cycling and boxing) and weights (i.e. upper and lower body weights). As reported by Ritchie et al. (2015) the majority of training loads observed in the early stages of an AFL preseason, are made up of skills (i.e. 600 ± 470 AU), running (i.e. 640 ± 1080 AU) and other conditioning (i.e. 740 ± 530 AU) (6). Furthermore, the intensity of training is also perceived to be higher in the early preseason phase, with research finding AF athletes report higher ratings of perceived exertion (RPE) and on average complete greater bouts of high-intensity running (i.e. 6680 ± 3540 m) (6).

The preseason phase also aims to improve strength and agility, with greater opportunities to practice change of direction and decision making during match-simulation sessions (2). In particular, developing strength and power with resistance training, can support the development of fat free soft tissue mass (FFSTM) and minimise non-functional fat mass (FM) (2). There are greater opportunities to maximise FFSTM during the preseason phase compared to during the competition season (2). Research in AF has found that with the inclusion of two to four strength sessions per week during preseason, athletes are able to develop FFSTM and decrease non-functional FM (8). Greater proportions of FFSTM are associated with greater sprint performance (2). Due to the intermittent high-intensity play observed in AF, sprint performance more specifically, repeated-sprint ability is an important physical trait required during AF match-play. The development of repeated sprint ability, is undertaken during the preseason phase to ensure athletes can manage the demands of competition (9). Training sessions during preseason will aim to expose athletes to a range of scenarios to develop their agility, with an aim to improve decision making and reaction time (2). An athlete's ability to make decisions under pressure, as well as to respond to opponents counter-movements is essential for match-play performance (2). Therefore, the preseason phase is an important period for athletes to develop and improve a range of physical qualities which are required for competition. It is also an essential time for athletes to condition their bodies to withstand the match-play volumes and loads observed during the competition season and to optimise their nutrition to enhance training adaptations (2).

During the competition phase, training loads performed throughout a typical training week are reduced to maximise athletes' recovery post competition (i.e. 1500-2000 AU per week) (6, 10). Approximately half of the competition season training loads are made up of match-play with the remaining allocated towards skills and resistance training (6). In particular, when compared to other football codes in Australia including the AFLW, AFL athletes on average cover greater distance and compete at greater intensities during competition (i.e. 11.0-13.5 km per match) (2). Much of this is performed at low speeds, however due to the intermittent nature of AF, research has reported that on average professional AF athletes cover 1300-4300 m of this distance by high speed running (HSR), at an intensity of 27 ± 7 m·min^{-1} (6, 10). In comparison, GPS data report that AFLW athletes cover on average significantly less total distance per game, with literature reporting that athletes cover 5.0-6.3 km per match (5). To manage cumulative fatigue, a typical training week will include one to two skill sessions with reduced training loads in combination with one to two resistance sessions that will focus mostly on upper body strength and the maintenance of FFSTM that has been gained prior to the competition phase (2).

During match-play, both anaerobic and aerobic energy systems will be used. In particular, anaerobic energy systems are required to fuel intermittent high-intensity sprints, with energy provided by the breakdown of intra-muscular glycogen and phosphocreatine (PCr) (11). For all other sub-maximal running that occurs during match-play, the aerobic energy system will be used to cover energy costs and will further support the resynthesis of PCr (11). In summary, the competition phase has a major focus on competition and recovery and therefore to account for total distance performed during match-play, training loads throughout the training week will be reduced (2).

2.1.3.1. Physical demands of AF Positions

AF athletes are divided into three positional groups; a) forwards (offensive), b) midfield or 'nomadic' and c) backs (defensive), with six athletes from each group on the field at any one time (Figure 3) (1, 2). Typically, the forwards and backs group will include a mix of taller key positions, in addition to smaller mobile athletes (i.e. half forward and back flanks) (2). The main role of the 'back or defensive' positional group is to defend against the opposition, whilst the forward positional group aims to score (2). Midfielders or 'nomadic' positions (i.e. centre, wings, followers and ruckman) are the main link defensive (between i.e. backs) and offensive (i.e. forwards) positions and will move the football up and down the surface of the ground (4).

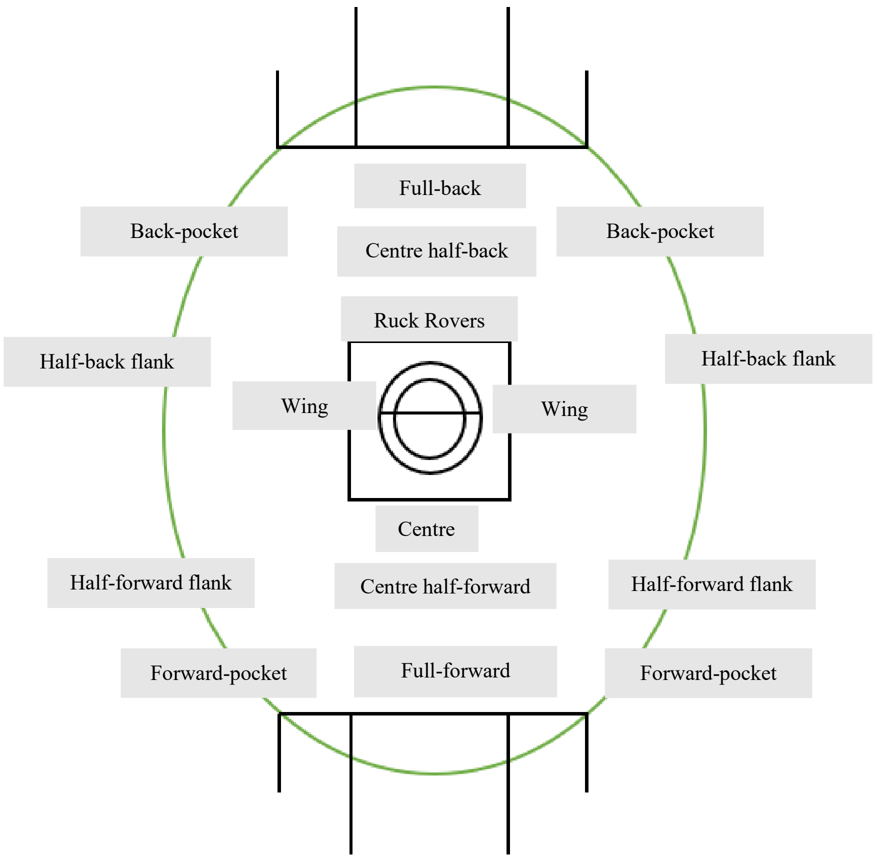

Figure 3. Australian Football positions on field

The figure above was adapted from 'Figure 1' presented by Johnson et al. (2018) (2)

Much of the research assessing average playing time and distance covered during match-play has been undertaken with AFL athletes (12). Research using GPS reports that midfielders cover the most distance, estimating that athletes cover on average 12.3 ± 2.0 km per match (12). In comparison, mean distance for forwards (N=121) and backs (N=122) has been reported as 11.3 ± 2.1 and 11.9 ± 1.9 km, respectively (12). GPS data has shown a downwards trend for total distance and HIR during match-play, which may be a result of fatigue (3). However, athletes that compete in AF, irrespective of position will need to be able to compete under fatigue and execute the technical skills required including ball skills and kicking (2). Not only is physical fitness important, an athlete's body composition will also play an important role in meeting performance demands and will differ depending on an athlete's AF position (1).

2.1.4. Anthropometric characteristics

AF athletes' physique, regardless of their competing position, is usually characterised by high amounts of FFSTM and low body fat (BF) level (4, 13). The majority of research has assessed male AF athletes anthropometric characteristics, with only one study reporting on the characteristics of semi-professional female AF athletes (i.e. 184.7 ± 7.7 cm and 82.0 ± 9.0 kg) (14). To date, no research has assessed the anthropometrics (i.e. body mass, height, FFTSM) of professional female AF athletes.

For male AF athletes, the development of FFSTM is important for a range of physical traits due to the strong correlations found between FFSTM and strength and power (4, 13). Therefore, there is a focus on the building and maintenance of FFSTM and where required a loss of excess FM (15). Furthermore, higher levels of FFSTM relative to BF, has been highlighted as a protective factor against injury, especially for younger development athletes (7). Body composition is commonly assessed over an AF season by high performance teams, to monitor for any significant changes in FFSTM and BF (8). The anthropometric characteristics (i.e. body mass and height) of AF athletes will vary depending on their on-field position, however limited research has assessed the FFSTM and body fat differences between AF positions (1). Research that has assessed these characteristics have found ruck positions are on average >200 cm in height and have a greater total mass in comparison to more mobile running players such as wings and small forwards (1, 15). The anthropometric profiles of AF athletes will also differ between the professional and semi-professional leagues (8). In particular, a systematic review by Johnston et al. (2018) reports that on average professional AF athletes have greater FFSTM levels, when compared to senior semi-professional AF athletes (2). Furthermore, professional AF athletes had lower BF levels in comparison to semi-professional AF athletes (2). Typical BF percentages (BF%) and skinfold measurements (SF, mm) for AF athletes include; for senior professional (n=94, BF%: 8.2 ± 1.9, sum of 7 SF: 47.2 ± 7.7 mm), youth professional (n=21, BF%:8.3 ± 2.7, SF: 57.9±15.9 mm) and semi-professional athletes (n=36, BF%: 13.7 ± 6.2, SF:57.6 ± 11.0 mm) (2).

Across an AFL season, research has highlighted that professional AF athletes' body composition fluctuates, especially during the preseason phase and during off season (8). Longitudinal research by Bilsborough et al. (2014) assessed the body composition of a group of AFL athletes over an AFL season and found most of the changes to body composition occurred in the preseason phase, with reductions in FM and increases in FFSTM observed (2, 8). Slight increases in FM were observed at the end of the competition season, which was likely a result of decreased training loads (2, 8). Weight loss practices that aim to reduce BF within short time periods should be avoided to prevent any detriment to performance and long-term health (16). Furthermore, within AF environments, there is a need to ensure body composition goals are individualised according to an athlete's needs (16). A position stand developed by the Academy of Nutrition and Dietetics, Dietitians of Canada and American College of Sports Medicine (ACSM) (2016), recommends that single and rigid body composition targets should not be advocated for groups, especially when working with athletes within team sport environments (16).

2.1.5. High Performance support teams in AF clubs

Within AF, a variety of professionals are employed to prepare athletes mentally and physically for performance. Very little research has explored the individual roles of each professional within these environments, however what is known is the importance of these teams in preparing athletes for competition (20). Medical professionals such as team doctors, underpin the multidisciplinary team found within AF environments, play an integral role in the monitoring of athletes' health and wellbeing (17). High performance support teams will include; physiotherapists, sport scientists, strength and conditioning coaches (including rehabilitation and strength coaches), myotherapists, sports trainers, podiatrist, psychologist and a sports dietitian (SDs) (18). This team will often be guided by an overarching high-performance manager, who will align these disciplines to promote the athlete centred approach (20).

In summary the planning of a periodised training program will include sport science, strength and conditioning, physiotherapy and medical disciplines, to ensure training goals are met and that athletes are well prepared to meet the demands of competition (20). Many of these professionals also play a role in rehabilitation and return to play programs. Sport scientists have a key role in the monitoring of training loads using GPS and in the development of protocols to assess athletes' responses to training and recovery (20). Furthermore, strength and conditioning coaches monitor athletes' recovery throughout the competition season and conduct power and strength testing. As a part of active recovery, myotherapists and physiotherapists together monitor athletes' muscle soreness throughout the training week and provide treatment where necessary (20). Sports nutrition professionals such as sports dietitians, who are a relatively new addition to AF high performance teams, will focus on the development of team and individualised nutrition programs which includes the monitoring of athletes' DIs and food habits, body composition, hydration status and recovery (*please see chapter 2.2.8. 'Role of the Sports Dietitian'*) (19). Multidisciplinary teams found in AF environments, will work together and have aligned goals with the purpose of optimising an athlete's performance.

2.1.4. Conclusion

In summary, athletes who compete in AF will need to possess a broad range of physical qualities including speed, agility, power and aerobic fitness, in order to manage the demands of match-play and training. Furthermore, past research indicates that male AF athletes have greater FFSTM and lower BF levels when compared with other team-based sports (1). However currently, there is limited research that has assessed the body composition of professional female AF athletes (i.e. FFSTM and BF%). Lower body mass (including lower levels of FFSTM) has been highlighted as an injury risk for athletes competing in AFL, especially for developing and younger athletes (7). In the AF team setting, it is essential that body composition is assessed and monitored over the pre and competition phases, to manage changes in body composition (i.e. changes to FM or FFSTM) and to develop strategies that promote performance advantages and good health. The role of nutrition within AF environments may have been previously overlooked, however research in the area of nutrition has evolved and highlights the benefits of optimal DI for athletic performance. Currently, sports nutrition recommendations are not sport specific, therefore an insight into the unique nutrition demands of AF athletes is required.

2.2. Nutrition Requirements of Australian Football Athletes

An extensive review of current sports nutrition recommendations has been undertaken and has been included as Appendix A. For the purpose of this thesis, Section 2.2. will specifically focus on the nutrition requirements of AF athletes.

2.2.1. Introduction

As previously mentioned in Section 2.1., AF athletes must demonstrate a broad range of physical qualities including high levels of speed, strength, agility, power and aerobic endurance to meet the demands of training and competition (4, 13). Furthermore, AF athletes require a focus on the optimisation of FFSTM and depending on individual athlete goals will aim to maintain or reduce of FM (16, 20). To provide guidance for sports nutrition professionals working within AF, there is a need to provide updated information regarding the nutrition requirements of athletes. Previously, a review by Ebert et al. (2002) provided an insight into the nutritional practices of AFL athletes (1). This review highlighted the importance of CHO and hydration strategies for training and competition and the need for future research to explore the nutrition requirements of AF athletes (1). Therefore, using background information collected in Section 2.1., current sports nutrition recommendations and available research, this section will aim to provide a summary of the nutrition requirements of AF athletes (21-26). Secondary, this section aims to identify research gaps in the literature regarding AF and provide insight into potential research opportunities in this area.

2.2.2 Energy requirements of AF athletes

2.2.2.1. Energy requirements for training and competition

Dietary planning that meets energy needs is essential for athletic performance and optimal recovery (21). When estimating professional AF athletes' energy requirements, sports nutrition professionals must take into consideration an athlete's energy output (including training and competition demands), sport centred goals including body composition goals (i.e. manipulate FFSTM and FM and their individual characteristics (i.e. age, gender, body mass, stature etc.). Negative energy balance, which can be a result of a mismatch between energy intake and expenditure for extended periods of time, is associated with losses in FFSTM, menstrual dysfunction in females, loss and decline in bone mineral density, an increased susceptibility to injury and illness, and increased symptoms of overtraining (i.e. fatigue) (16, 27). In comparison, a positive energy balance or diets that focus on an energy surplus, is beneficial for the development of FFSTM by stimulating anabolic processes (24). Athlete monitoring is required, especially with younger athletes to avoid excess total mass and BF gains which may influence performance and increase the risk of injury (28). Sports nutrition recommendations advocate for the consumption of adequate energy to maintain bodily function, overall health and to fuel performance (16).

Current recommendations advocated by the ISSN are 25-35 kcal per kg of body mass per day ($kcal \cdot kg^{-1} \cdot day^{-1}$) (exercising 30-40 minutes per day; 3 times per week and 40-70 $kcal \cdot kg^{-1} \cdot day^{-1}$ (exercising 2-3 hr per day of intense exercise; 5-6 times per week) (21). During an AF preseason, athletes have greater energy demands throughout a training week, with high volumes of training required to improve aerobic capacity and fitness (8). In comparison, during the competition season phase, training loads may be reduced during the training week, to adjust for high volumes performed during match-play (8). Furthermore, in team sport environments such as AF, high performance teams periodise training sessions and loads throughout a training week (i.e. high vs low intensity sessions) to adjust for competition and recovery demands (3, 29). In recent times, new research has been undertaken to explore the use of a periodised approach to nutrition. Periodised nutrition is a term that describes dietary advice that manipulates an athlete's DI over time (i.e. over a training week) according to their training needs to promote training adaptations (30). Therefore, energy intakes should follow a periodised approach to ensure energy intake matches training outputs (30). Periodising an athlete's energy intake can promote training adaptations and may additionally help athletes to optimise body composition (30). Further research is required to measure and estimate the energy expenditure of AF training and competition loads. For sports nutrition professionals working in AF, this information may be useful as a guide when estimating athletes' energy requirements.

2.2.3. CHO recommendations for AF athletes

2.2.3.1. CHO training needs

CHO containing foods provide a source of glucose and depending on the exercise intensity, duration and availability of fuel, the body will use CHO as a major fuel source during physical activity (16, 25). Due to the intermittent and aerobic nature of AF and the duration of training (*Please refer to Table 3.)* and match-play (i.e. >90 minutes), CHO is an important fuel source (16, 25). Currently, sports nutrition recommendations related to CHO intake advocate a broad range of 5-10 g of CHO, per kg of body mass per day ($g \cdot kg^{-1} \cdot day^{-1}$) (21). It is important advice related to carbohydrate intake is periodised to align with training (i.e. main, light and recovery days) and match-play demands (3, 29). In particular, the consumption of consistently high CHO intakes (i.e. 5-10 $g \cdot kg^{-1} \cdot day^{-1}$) throughout a training week, may not be appropriate for AF athletes (31).

The practicality of consuming high doses of CHO (i.e. 8-10 $g \cdot kg^{-1} \cdot day^{-1}$) and exceeding overall energy requirements, especially when there is a need to maintain optimal body composition, has been questioned by researchers working in team based sports such as AF (32). Research by Routledge et al. (2020), explored the habitual intakes of a professional AF team and found significant differences when CHO intakes were assessed across a training week ($P<0.001$) (32). AF athletes were found to follow a periodised approach with the greatest absolute CHO intake consumed one day prior to match day (32). In comparison the lowest absolute CHO intake was reported on a recovery day (i.e. no activity recorded) (32). However, athletes' overall CHO intakes were found to be low, with the authors identifying the potential influence of underreporting (32). Athletes included in this research study were not following a specific nutrition program, however had received prior education regarding CHO fuelling pre competition (32). Therefore, it may be suggested that to ensure AF athletes consume CHO relative to training and competition needs, greater access to individualised dietary advice may be beneficial.

Table 3. Example of periodised CHO intake across an AF preseason training block based on the theoretical framework of 'Fuel for the work required' model. (26)

Training Session	CHO Recommendation
Day 1: Main training *Skills session approximately 2-3 hrs* *Strength session approximately 60-90 minutes*	HIGH (>5 $g \cdot kg^{-1} \cdot day^{-1}$)
Day 2: Light Training day *Light Skills Session approximately 1-1.5 hrs* *Strength session approximately 60-90 minutes*	LOW-MODERATE (3-5 $g \cdot kg^{-1} \cdot day^{-1}$)
Day 3: Main training *Skills session approximately 2-3 hrs* *Strength session approximately 60-90 minutes*	HIGH (>5 $g \cdot kg^{-1} \cdot day^{-1}$)
Day 4: Recovery day *No recorded activity*	RECOVERY <3 $g \cdot kg^{-1} \cdot day^{-1}$*(CHO *Fuelling required for Day 5)*
Day 5: Main training *Skills session approximately 2-3 hrs* *Strength session approximately 60-90 minutes*	HIGH (>5 $g \cdot kg^{-1} \cdot day^{-1}$)

NB: *This has been developed as an example, timing of weekly training sessions will be dependent on each AF club requirements. Furthermore (*), CHO requirements will need to be tailored according to individual athlete goals.*

More recently, greater research has been undertaken in athletic populations to assess the efficacy of dietary manipulation strategies such as 'Fuel for the work required' on training outcomes (26). In particular, Impey et al. (2018) suggests that by manipulating CHO availability across a training week, training adaptations can be enhanced (26). Recent work by Burke et al. (2018), provides greater context into exercise-diet strategies including 'Train low, compete high' and 'CHO periodisation', highlighting the importance of an individualised approach to nutrition which should be based on evidence based practice (31).

Interestingly, a study by Anderson et al. (2015) highlighted the potential use of CHO periodisation within a professional sport squad, highlighting the periodised nature of daily training

training and accumulative weekly loads within a 3 week time frame (i.e. reduction of total distance and intensity for match-day) (33). Although AF training loads are reportedly higher in comparison to loads observed in soccer, this knowledge is transferrable as training loads will be tapered over pre and competition phases (33). An example CHO periodisation plan, based on a typical AF preseason training week is presented in Table 3. (33).

It is important for AF athletes to consume adequate amounts of CHO in preparation for aerobic performance (match-play). However, it is understood there are challenges associated with estimating the glycogen cost of training within different team sports, which may include professionals under or overestimating athletes' CHO requirements (26, 34). Currently limited research is available that assesses AF athletes' DIs across a training week. Therefore, to provide further insight into the use of dietary manipulation strategies within AF, future research should aim to assess the dietary patterns of AF athletes' (i.e. male and female) across a training week and identify whether athletes meet total CHO recommendations and/or follow a periodised approach as observed by Routledge et al. (2020) (32).

2.2.3.2. CHO recommendations during and after match-play

When determining an athlete's CHO needs for match-play and recovery, key factors including the duration of activity, type of CHO (i.e. glucose, sucrose, fructose and maltodextrin) and tolerance to feeding (i.e. gastrointestinal tract (GIT) symptoms) should be evaluated prior to competition (21). For AF athletes, the duration of exercise will be a key variable to consider when determining match-play CHO requirements. For example, the duration of an AF match can be up to two hours, therefore using current recommendations CHO should be consumed at a rate of 60 g per hour, using single or multiple transportable CHO (21). Recently, research by Routledge et al. (2018) explored the CHO needs of AF athletes during match-play (35). Authors highlighted that the dietary manipulation of CHO in the days prior to competition (i.e. 48-72 hours) may be appropriate to meet glycogen demands of working muscles, in comparison to CHO feeding undertaken during activity (Table 4) (35).

Table 4. Example of periodised CHO intake prior to competition based on research by Burke et al. (2004) Routledge et al. (2018) (35, 36)

CHO Fuelling pre match-play			
1-2 days before game day	**HIGH** >6 g·kg^{-1}·day^{-1}		
	Pre match meal	**During Match**	**Meal – 1-4 hrs post**
Game day	HIGH (2 g·kg^{-1})	*CHO feeding during match- play as per individual player needs.*	HIGH (1.0-1.2 g·kg^{-1})

***NB:** This has been developed as an example,* CHO *requirements will need to be tailored according to individual needs.*

Furthermore, based on the nature of the sport, AF match-play can use energy provided interchangeably by aerobic and anaerobic systems, hence, it is important for athletes to increase their glycogen stores in the liver and muscle, prior to activity to prevent any symptoms of fatigue (11). Additionally, for exercise up to 75 minutes in duration CHO mouth rinses have been found to have beneficial effects on performance via the stimulation of the central nervous system and the brain (16). Similar performance benefits have been found between mouth rinsing and the ingestion of a CHO fluid (37). For example, AFLW athletes during competition may not require large CHO feedings due to the duration (i.e. up to 60 minutes) and reduced workloads (i.e. lower total distance compared to AFL) observed and instead may benefit from the inclusion of CHO mouth rinses throughout competition (37).

Furthermore, CHO is also important for recovery following intense exercise (i.e. post training and competition) and has been found to accelerate muscle glycogen resynthesis (21). AF athletes should focus on the inclusion of a CHO rich meal in combination with protein, following intense physical activity (i.e. 1 g·kg^{-1} CHO and 0.5 g·kg^{-1} of protein) (21). In addition, where feasible a high CHO meal should be included within two hours post activity (21). Therefore, a focus on the dietary planning prior to competition may be of particular importance for sports nutrition professionals working with AF athletes (35). Where possible, CHO intakes should still aim to follow a periodised approach, taking into consideration decreased training loads observed during the competition phase (8, 38).

2.2.4. Protein recommendations for AF athletes

The importance of dietary protein for muscle protein synthesis (MPS) and recovery is well established in the literature (21, 22). For the building and maintenance of FFSTM, AF athletes should aim for 1.4-2.0 grams of protein of per kg of body mass per day ($g \cdot kg^{-1} \cdot day^{-1}$) (21, 22). Novel research has highlighted that higher protein intakes (i.e. > 3.0 $g \cdot kg^{-1} \cdot day^{-1}$) may be beneficial for the maintenance of FFSTM during hypocaloric periods (i.e. during an energy deficit) (21). Research by Longland et al. (2016) supports the use of high protein diets (i.e. >2.4 $g \cdot kg^{-1} \cdot day^{-1}$) to promote increases in FFSTM, when an energy deficit is undertaken to manipulate FM (39). Authors observed significant increases in FFSTM in participants (i.e. young men) who consumed a high protein diet under hypocaloric conditions, in comparison to those that consumed a standard protein intake (i.e. 1.2 $g \cdot kg^{-1} \cdot day^{-1}$) during a 4-week training period (39). Although novel, this research highlights the importance of protein intakes during periods where hypocaloric conditions may be observed. Taken as a whole, during high-intensity training loads or when an individual is aiming to adjust body composition (i.e. reduce BF and maintain FFSTM) higher protein intakes (i.e. > 2.4 $g \cdot kg^{-1} \cdot day^{-1}$) may be beneficial (39).

2.2.4.1. Protein dose and distribution

For athletes aiming to maximise MPS, recommendations suggest it is important to focus on the dose, quality and distribution of protein intakes over a training day (21). Practical judgement should be made when determining the 'ideal absolute dose' appropriate for different athletes and should additionally consider their individual characteristics such as age, body mass and experience. (22). Sports nutrition recommendations advocate that an absolute dose of 20-40 g or approximately 0.2-0.55 g per kg of body mass, is required to stimulate MPS (21). Furthermore, to optimise the absorption of protein, intake of protein doses should be distributed evenly over the day (i.e. every three to four hours), with a specific bolus of protein before sleep (21). The dose range of 20-40 g, has been developed based on a variety of research that has explored and compared the ‘optimal dose’ for MPS, in different athletic populations (40, 41). In particular, research by Areta et al. (2013) highlights that a 20 g absolute dose, distributed evenly over the day (i.e. four servings) can enhance MPS, in the absence of an exercise stimulus (40). However, for older athletes or after whole body resistance training, research by McNaughton et al. (2016) identifies that a 40 g dose of protein (i.e. whey protein) may be required (41). Taken together, this research highlights that an athlete’s training status including their experience and age and the type of training undertaken, are key variables to consider when determining an individuals’ optimal protein dose (40, 41). Furthermore, it is important to note that currently research that has assessed ingested-protein dose responses, has been conducted using young male cohorts, with no research available on female athletes (42). Future research exploring protein dose responses in professional female athletes is required. Therefore, to promote MPS and gains in FFSTM during the preseason where whole body resistance training is conducted, AF athletes may benefit from larger protein doses (i.e. 40 g). In comparison a smaller dose (i.e. 20g) may be appropriate on training days when no physical activity is performed (i.e. recovery days) (40, 41).

2.2.4.2. Protein Quality

The bioavailability of amino acids (AA) found in food sources of protein will vary, with animal (meat, poultry, eggs, fish and seafood) and dairy (milk, yoghurt, cheese etc.) proteins sources found to contain a greater percentage of essential amino acids (EAAs), when compared to plant based protein sources (tofu, legumes, nuts and seeds etc.) (22). Because of this, greater rates of MPS are found when animal and dairy based protein sources are consumed, in combination with resistance-based exercise (22). The effectiveness of different protein sources on MPS (i.e. soy, casein and whey protein) has been explored in healthy male cohorts (43). Authors identify that greater rates of MPS are found with the consumption of whey hydrolysate protein, in comparison to isolated soy and casein protein (43). When compared to isolate soy and casein respectively, whey hydrolysate protein contains a greater concentration of leucine and is rapidly digested (43). Leucine is a branched-chain amino acid (BCAA) which has an important role in protein synthesis, due to its role in activating key signalling proteins (44). In particular an optimal dose of 700-3000 mg of leucine is suggested to maximise rates of MPS (22). Smaller increases in blood BCAAs and Leucine have been found after the ingestion of plant based protein sources such as soy, when compared to animal based protein derivatives (i.e. whey) (43, 44). Therefore, for AF athletes where gains in FFSTM are required for power and strength, animal-based protein sources such as dairy, may provide a more efficient protein source to promote MPS (22). For vegan or vegetarian athletes, MPS can still be achieved following a plant-based diet, however it is important that individualised dietary planning is undertaken to ensure athletes consume the quantity and quality of protein required to achieve their goals.

As mentioned earlier, protein sources can also be classed by their digestive rates including those that are digested and absorbed rapidly (i.e. whey isolate, soy protein) versus those that are slowly released (i.e. casein) (44). When rapid recovery is required post training or competition, fast release sources of protein including whey isolate, may be used to optimise recovery (44). Furthermore, recovery can be enhanced by combining post-exercise protein with CHO, which has been shown to improve rates of muscle glycogen resynthesis and alleviate muscle damage markers post activity (22). In comparison, slow release proteins such as casein (i.e. dairy products) may be used to prevent whole-body protein loss, which can occur as a result of negative protein balance after an overnight fast (21, 45). Therefore, dairy-protein based strategies prior to bed may be particularly relevant for semi-professional AF athletes, who train in the evening, to optimise recovery and to increase MPS rates (45).

In summary, MPS and recovery post-exercise can be optimised with a particular focus on the quality, quantity and timing of protein intake (22). When determining an AF athletes' protein needs, it is important to take into consideration individual characteristics including; age, gender, experience and the goals and requirements of different AF positions (i.e. ruck versus wing). It is important to note, that whilst protein is an important nutrient for training adaptations such as FFSTM gains, a focus on overall energy intake is also essential (21, 22).

2.2.5. Dietary fat recommendations for AF athletes

Adequate fat intake (i.e. lipids) can help athletes achieve energy requirements and can additionally support immune function and recovery (21). Lipids, especially those with anti-inflammatory properties, have been found to optimise recovery post-exercise and support the prevention of injury and illness within athletic populations (46). In particular, omega 3-fatty acids (i.e. docosahexaenoic acid and eicosapentaenoic acid) which are predominately found in fatty fish and fish oils, have been positively linked to the prevention and treatment of exercise induced muscle inflammation (21, 46, 47). Sports nutrition recommendations suggest a moderate intake of fat (i.e. 30% total energy (TE)), however needs will be based on individual athlete goals (21). In particular, for athletes where a reduction in FM is required, modest fat intakes may be advised (i.e. 0.5-1 $g \cdot kg^{-1} \cdot day^{-1}$ of fat , or approx. 20% TE per day) (21).

Currently there is growing interest in the use of fat adaptation dietary strategies such as low CHO, high fat (LCHF) and ketogenic diets, within athletic populations to promote performance advantages (48). LCHF strategies have been found to upregulate the use of endogenous and exogenous fat stores, by increasing the activity of hormone sensitive lipase (HSL) (21, 48). Research suggests the mechanisms upregulated by LCHF strategies, can result in decreased metabolic flexibility and downregulate CHO oxidation (21, 48). In particular, a research study in professional race walkers by Burke et al. (2017) found that a LCHF diet increased the oxygen costs of physical activity and impaired performance when compared to a periodised-high CHO diet (48). Furthermore, an athlete's ability to compete at high intensities, may also be impaired by the use of these dietary strategies (48). Due to the intermittent nature of AF match-play, it is important that glycogen stores are available to fuel the demands of working muscles, which is limited with LCHF diets (25). More recently, the effects of fat adaptation strategies on markers of bone health have also been explored, with research by Heikura et al. (2020) finding that in professional race walkers, markers of bone modelling and remodelling were impaired, as a result of a short-term ketogenic dietary trial (49). Research is required to further assess the influence of these strategies (i.e. LCHF) on athletic performance and health. For AF athletes, there is evidence to support the use of a periodised approach to nutrition with a focus on tailoring CHO availability surrounding competition and large training loads (26, 30, 48).

2.2.6. Micronutrients

Consuming a diet that contains a variety of foods with adequate energy intake, should support athletes to meet their micronutrient needs (16, 50). Micronutrients play a vital role in normal bodily function and can protect against oxidative stress, maintain cell and bone health, promote energy synthesis and support immune function (51, 52). For the athletic population, calcium is particularly important for bone health and in the prevention of injury (21, 53). Furthermore, iron is important for the transport of oxygen which regulates energy release (21, 53). The ISSN recommends micronutrient intakes should align with population guidelines for calcium and iron (i.e. Recommended dietary allowances (RDA)) (21). For Australian athletes, these guidelines are known as the Nutrient Reference Values (NRV) (21, 54). Therefore, to promote health and wellbeing, athletes should follow RDI guidelines for calcium (i.e. for males and females 19-50 years: 1000 mg·day^{-1}) and iron (i.e. males and females 19-30 years: 8 mg·day^{-1} and 18 mg·day^{-1}, respectively) (54). In particular, research has highlighted female athletes are more vulnerable to micronutrient deficiencies such as iron, due to increased loss through menstruation (55). Therefore for professionals working with female AF athletes, it is important that nutrition advice ensures athletes meet their micronutrient needs (55). To date, no research has explored professional female AF athletes' DIs including micronutrient intake. Therefore, future research is required to assess the dietary behaviours and nutrition knowledge of professional female AF athletes, to provide a baseline insight for sports nutrition professionals working within AFLW environments.

2.2.7. Fluid recommendations for AF athletes

Monitoring athletes' hydration status is crucial for the prevention of dehydration during training and competition (50, 56). In preparation for training and competition, athletes should aim for an euhydrated state, to optimise thermoregulation and to prevent metabolic strain (56). Impairments to performance including cognitive decline and fatigue are associated with fluid losses over ~2%

of body mass. For losses over 4% of body mass, athletes are at an increased risk of heat exhaustion and heat-related illness (i.e. nausea and heat stroke) (21).

Careful monitoring of hydration during competition is important to prevent excessive fluid loss, especially where the duration of match-play exceeds two hours (57). During preseason training periods, athletes are exposed to hot and humid conditions, with thermoregulation strategies key (i.e. monitoring fluid loss and hydration status) to monitor fluid balance and to prevent symptoms of dehydration. Hydration may be overlooked during the competition season, which is predominately played in cooler climates (i.e. ~10-15 °C) (1). However monitoring of fluid balance, is just as important during match-play to prevent fatigue and cognitive decline (1). There are opportunities for AF athletes to maintain their hydration status during match-play, with time available to consume fluid throughout the game (i.e. trainers provide fluid on field during pauses in play) and during quarter and half time breaks (58). Simple techniques such as the measurement of fluid lost post-exercise via weigh in and simple advice such as to consume a volume up to 150% of net fluid loss can help athletes to optimise their hydration status especially when rapid recovery is required (i.e. preseason training week) (59). However, it is important hydration protocols consider the duration and intensity of exercise, as well as individual athlete preferences (i.e. GIT tolerance) (59).

In addition, pre-event sodium loading (i.e. one to two hours pre-event) has been found to improve thermoregulation and rates of fluid retention during activity with strategies recommending 20-40 $g \cdot kg^{-1}$ of sodium, with 10 $mL \cdot kg^{-1}$ fluid prior to competition (59). Furthermore, to optimise post-exercise hydration, the inclusion of a CHO rich meal in combination with fluid has been shown to improve rates of fluid retention and to minimise urinary losses (59). Currently, there is a need to assess hydration practices in AF and provide standardised guidelines that meet the performance needs of AF athletes' during training and competition scenarios. For AF athletes, assessment of hydration status and the development of hydration protocols should ideally be undertaken during preseason training phases, to identify tolerance (1). Greater plasma volume retention has been found with electrolyte replacement during exercise, in comparison to hydration strategies that focus on the intake of water alone (59). To enhance fluid retention during activity, ORS appear to provide the best solution, and have been found to enable the retention of more fluid and smaller total urine masses when compared to water (60). Novel research by Maughan et al. (2015) developed the beverage hydration index (BHI) to provide insight into the hydration properties of different drink beverages with greater rates of fluid retention found with ORS, milk and skimmed milk, these are summarised in Table 5 (60).

Table 5. The nutrition content and Beverage Hydration Index of commonly used fluids

Item	CHO (g)	Sucrose (g)	Glucose (g)	Sodium (mg)	Potassium (mg)	Magnesium (mg)	BHI *(if significantly different to water)*
Sports Drink	6.0	5.5	0.5	51	22.5	NA	NA
Electrolyte solution	2	0	2	105	85	NA	1.54 ± 0.74*
Milk-regular fat	6.2	NA	NA	36	143	10.3	1.50 ± 0.58*
Skimmed milk	5	NA	NA	51	171	12.5	1.58 ± 0.60*
Orange juice	6.1	NA	NA	2.5	154	8.3	NA
Cola	10.9	NA	NA	10	1	1	NA
Coffee	1.1	NA	NA	11	65	13	NA

NB: *The above information nutrient analysis was provided by Foodworks Version 8, Xyris, Queensland, using generic food and beverage items, The Beverage Hydration index information was cited from research by Maughan et al. (2015) (60).*

2.2.8. Role of the Sports Nutrition Professional in AF

Currently all teams competing in the AFL employ a sports nutrition professional (i.e. SDs) to provide nutrition advice to support athletes to meet their training and performance goals. Resources invested into nutrition services will range with most SDs in the AFL employed one to two days per week, with an additional role on match days and for team travel (19). Within AFLW environments, access to a sports dietitian may range depending on budget constraints, however the value of nutrition services within these environments has grown. Initially, not all teams in the AFLW provided access to nutrition services and intervention, however with the completion of the most recent season all teams now employ a sports dietitian on a casual or part-time basis.

Nutrition programs will differ amongst AF teams in what is provided; however, they will usually include the below nutrition services (19):

- Anthropometric monitoring of body composition (i.e. Skinfolds (mm), body mass (kg) and height (cm) and where available DXA scan.
- Group Education programs which include a variety of activities including; cooking classes, group lectures, practical skills (i.e. grocery tours, label reading) and induction programs for young athletes.
- Monitoring and organisation of game day nutrition strategies; pre and post-match meals, hydration and facilitating game day nutrition plans.
- Monitoring and management of supplement programs.
- Individualised nutrition consults including tailored meal plans and strategies for training and match day.
- Organisation of catering to optimise nutrition for training, match day and travel needs.
- Provision of sports nutrition resources including nutrition education message boards and recipes.

2.2.9. Conclusion

Athletes that compete in AF will have unique nutrition demands and therefore will require individualised dietary planning to meet training and performance outcomes. Currently, sports nutrition recommendations provide broad ranges to guide practice and therefore to translate these into practical dietary advice, sports nutrition professionals must have an understanding of training loads, match-play demands and individual athlete goals, to ensure dietary advice is tailored. To identify the gaps in nutrition, future research should further explore dietary and behavioural practices of team sport athletes such as AF, compare them to current sports nutrition recommendations. Limited research has explored the nutrition needs of AF athletes and no research has assessed professional female AF athletes' DIs, therefore future research in this area is required.

2.3. Factors that Influence the Dietary Intakes of Professional Athletes

2.3.1. Introduction

Appropriate nutritional intakes, which meet athletes' energy and macronutrient needs have been positively linked to athletic performance (16, 21). The importance of consuming a diet that meets training and competition needs has been outlined in Section 2.2. *(Nutrition Requirements for Australian Football Athletes)*, however research has found many team sport athletes including AF athletes consume DIs that do not align with sports nutrition recommendations (15, 50, 61). Therefore, to support food choice and dietary behaviours that promote performance and health, exploration into the factors that influence athletes' food choice and dietary behaviours is required (5). A review by Birkenhead and Slater (2015) describes the multi-dimensional nature of food selection and the variety of factors that motivate food choice, with authors highlighting that for professional athletes, performance is commonly reported as a main driver of food choice (62). The processes behind food choice can be described as an individual's 'personal food system' which is shaped and influenced by range of factors (Figure 4) (5). Eating behaviours are established throughout an individual's life and can be additionally shaped by their external environment (63). Therefore, when modifying any dietary habits, advice will need to be suited to individual preferences and must be supported in the long term to enable sustainable change (63).

A variety of models have been used to explain the processes behind food choice (62, 64). However, to develop dietary strategies that support and motivate behaviour change and guide athletes to meet their nutrition goals, there is a need to investigate the factors that influence food choice (62, 64). This section aims to provide a summary and critical review of the scientific literature that explores factors that influence professional athletes' DI. Using the factors described by Birkenhead and Slater (2015), the following areas will be explored: 1) Psychological, 2) Nutrition knowledge and access to nutrition services, 3) Interpersonal , 4) Physiological and 5) Time (62).

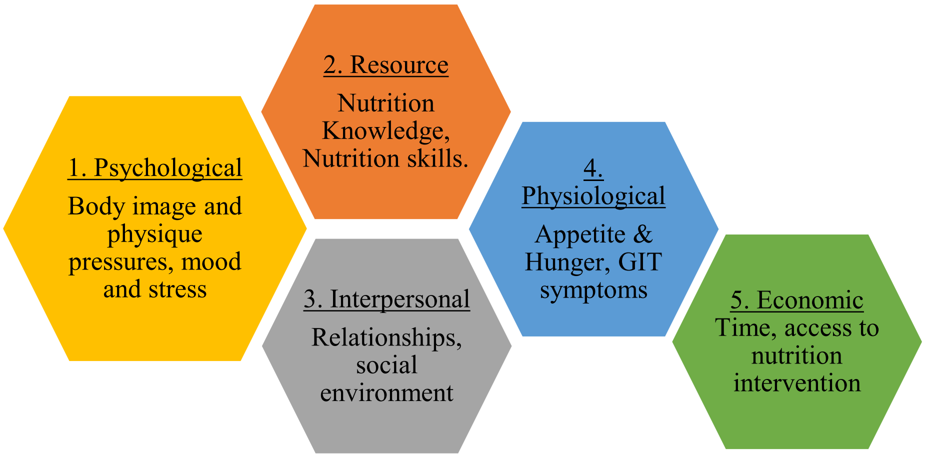

Figure 4. Factors that may influence an athlete's food choice
Figure 4 was adapted from the main theories explored by Birkenhead and Slater's (2015) review (62)

2.3.2. Psychological

2.3.2.1. Body composition and physique pressures

Achieving an ideal body composition with a focus on increasing FFSTM relative to FM for performance is well recognised in the literature (65, 66). Research has identified that athletes are becoming increasingly susceptible to experiencing pressures associated with achieving a desired lean and athletic physique, in particular in sports where low BF and total mass is emphasised (62). Body composition goals will vary between different individual and team-based sports (16, 20). Section 2.1. reveals that AF athletes require a greater level of FFSTM relative to FM in order to meet the physical demands of the sport (i.e. agility, power and speed) (16, 20). With greater pressures evident, consistent monitoring and proper dietary planning is essential to decrease the risk of any physiological and psychological side effects which may influence athletic performance and overall health (16, 27).

An individualised approach is important when determining body composition goals, with the ISSN recommending that rigid body composition targets should not be advocated for groups of athletes and teams (65). Research has identified that strict and rigid body composition goals may negatively influence athletes meeting their nutrition goals, with overly restrictive DIs often observed (16). In 2014, the International Olympic Committee (IOC), published a consensus statement on low energy availability (LEA) which occurs when there is a mismatch between energy intake and energy expenditure during training and competition (Figure 5 and Table 6) (65). This definition is an updated term from the previously known 'female athlete triad' as it now includes male athletes (27). In particular, athletes that compete in weight category or weight driven sports such as cycling, running, rowing and weight combat sports, have been identified as potential groups at risk of LEA (27). LEA is not only limited to athletes who compete in these sports, with many other team and individual sport athletes also identified to be at risk especially where a focus on body composition is evident (16). Prolonged inadequate energy intake, to meet body composition goals (i.e. to make weight) has been highlighted as a risk factor for Relative energy deficiency in sport (RED-S) syndrome (27).

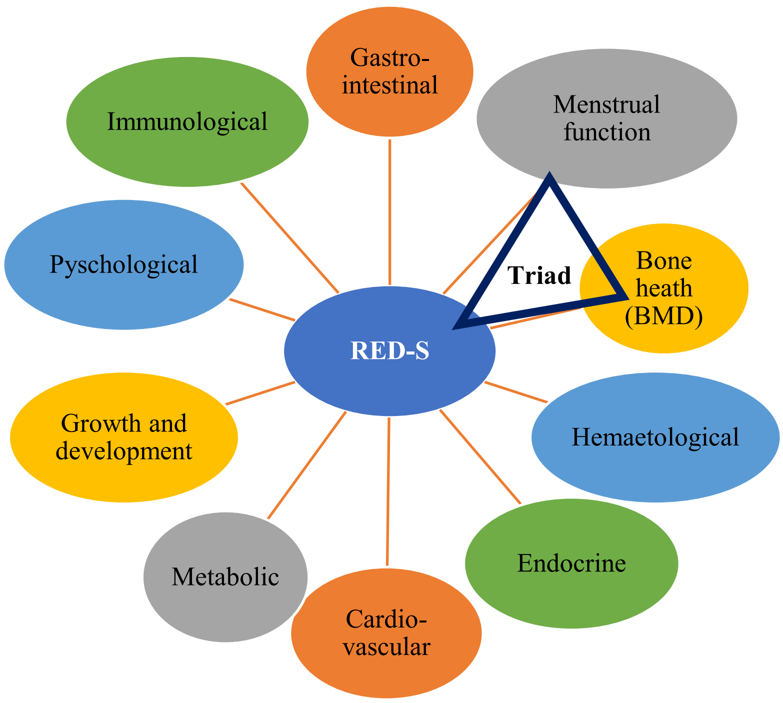

Figure 5. Features of Relative energy deficiency in sport (RED-S) syndrome (65)
Abbreviations: BMD; Bone Mineral Density
Figure 5 was adapted from International Olympic Committee position stand (2018) on RED-S in sport (65)

Birkenhead and Slater (2015) identify body image and weight control as major influences on food choice, especially for athletes concerned with meeting body composition goals (62). For team sport athletes such as AF, it is crucial that a multi-disciplinary approach is used to develop body composition goals and that rigid targets for groups are avoided (16). Body composition goals developed for AF athletes need to be individualised to their position and training needs (16). It is recommended that changes to body composition should be avoided around competition and that consistent monitoring is required to prevent LEA, especially during periods where high training loads are evident (i.e. Preseason) (16). Currently, limited research has assessed the influence of body composition goals on team sport athletes' DI and food choice. With regards to AF, where physique characteristics are evident (i.e. high amount of FFSTM and low BF levels) an insight into athletes' perceptions regarding body composition and whether meeting goals influence their food choice would be beneficial for professionals working with these athletes, to identify best ways to support athletes in meeting their performance and recovery goals.

Table 6. Physiological, psychological and performance consequences of RED-S (IOC 2018) (65)

	PHYSIOLOGICAL	**PSYCHOLOGICAL**	**PERFORMANCE EFFECTS**
RED-S	Decreased muscle glycogen stores	Depression	Decreased endurance performance
	Decreased muscle strength	Irritability	Decreased concentration and coordination
	Increased injury risk		Impaired judgement
	Decreased training adaption		

2.3.2.2. The influence of stress (i.e. mood)

Psychological and physiological stress can influence a variety of normal bodily functions (67). In particular, an increased production of stress hormones such as cortisol, can influence mood and alter overall food intake (67). Limited research has explored the influence of stress on mood and related dietary behaviours within athletic populations. For non-athletic populations, it has been identified that an increased production of cortisol can stimulate the ingestion of energy-dense foods and is associated with body mass gain (68). Due to the nature of professional sport, athletes will be exposed to a variety of performance and competition stressors, which without support may limit performance. To understand the relationship between stress, mood and DI in athletic populations, future research should aim to explore athletes' perceptions, sources of stress and influence on DI behaviours.

2.3.3. Nutrition Knowledge and Skills

2.3.3.1. Nutrition Knowledge

NK has been identified as a modifiable determinant of DI behaviours and has been explored by two systematic reviews in the past 10 years (69, 70). Heaney et al. (2011) and Trakman et al. (2016) provide an assessment of professional and semi-professional athletes NK status and identify that many athletes have poor NK (69, 70). Interestingly, no significant differences were found between NK status when professional male and female athletes where compared, with weak positive relationships found between NK and DI (69). Together, authors identify the need for future research to explore the development of validated NK tools, in order to explore the significance of these relationships (69, 70).

Limited research has assessed the NK of AF athletes, with no research available to provide insight into the NK status of professional female AF athletes (61, 71). In particular, research by Devlin et al. (2017) assessed the NK of professional AF athletes using the General Nutrition for Knowledge Questionnaire (GNKQ) and found no significant differences between NK of professional (i.e. AFL and semi-professional (i.e. VFL) (Mean score accuracy- AFL: 58% and VFL: 57%) (61). Australian Football athletes performed poorly in NK sub-sections that explored knowledge regarding sources of fat including saturated and unsaturated fat (61). Understanding an athlete's NK gaps can help sports nutrition professionals tailor nutrition education to an athlete's needs. It is likely that AF athletes would benefit from greater access to nutrition education, specific to their NK gaps. Devlin et al, (2017) additionally assessed relationships between DI and a range of variables finding positive associations between NK and total energy (P=0.01), NK and CHO (P=0.04) intake and NK and FFSTM (P=0.04) (61). These results further highlight the importance of providing nutrition education to support positive improvements in NK, which as a result may promote dietary behaviours and body composition changes (i.e. increased FFSTM).

More recently there has been a variety of improvements made to NK assessment tools including greater validation, greater demographic analysis, reduced length of questionnaire and the inclusion of visual based questions (*Appendix B*) (72, 73). In particular, the recently validated NSKQ was developed by Trakman et al. (2017) and provides a tool for sports nutrition professionals to accurately assess the NK status of teams and individual athletes and can be used to determine the efficacy of nutrition education strategies (19). Future research should aim to provide an updated assessment of AF athletes' NK using a validated questionnaire such as the NKSQ. In addition, research should aim to provide a baseline and assessment of professional female AF athletes' NK, to identify knowledge gaps and nutrition education needs.

2.3.3.2. Nutrition-based Skills

To translate knowledge into practice, nutrition education should aim to support the development of both declarative and procedural based NK (74). Procedural based NK known as the 'Practice' of good nutrition, includes the planning, purchasing and preparation of food (74, 75). It is unlikely that healthy food habits can be supported by declarative NK alone and to translate knowledge, the inclusion of food based skills such as preparation and cooking, within nutrition education programs is essential (75). Nutrition education programs that have focussed on improving professional athletes' NK and DI has been explored (76, 77). In particular, a study by Valliant et al. (2012) assessed the efficacy of an registered dietitian (RD) developed nutrition program on the NK status and DIs of college volleyball athletes (77). Improvements in diet quality were found post program, with significant improvements found in athletes' energy (P=0.002), CHO (P=0.01), protein intakes (P=0.01) and NK (P=0.001) (77).

Improvements in self-efficacy, health, and dietary outcomes, have been observed in non-athletic populations with the inclusion of nutrition education programs that focus on nutrition based skills such as cooking, label reading and shopping tours (78). For professional Australian athletes, research has identified that a lack of confidence in nutrition based skills such as cooking, has been perceived by as a barrier to food choice and meeting nutrition goals (79). In particular, younger athletes may require additional nutrition education with research identifying that food based skills are often limited in younger, inexperienced athletes (79). Nutrition education programs which have focused on the combination of theory and skill-based learning (e.g. cooking programs), have reported improved confidence, high feasibility and greater social interaction (80). Research by Ellis et al. (2018) found that post completion of a cooking education intervention with collegiate athletes, significant improvements in self-efficacy in food selection (P=0.002) and food preparation (P=0.001) were observed (81). To date, no research has explored efficacy of cooking and skills-based programs with AF athletes, however it may be suggested that previous work in collegiate athletes of a similar age group, may be transferable. Given the benefits of improved self-efficacy found with nutrition education and food-based skill programs, future research should explore the efficacy of nutrition education programs with AF athletes.

2.3.3.3. Access to Individualised Nutrition Advice

The role of the sports nutrition professional may be seen in some professional sport environments as an optional service and as a result athletes' access to individualised nutrition advice may be limited. Sports nutrition professionals such as Sports dietitians, play a role in optimising athletes' DIs to promote training, recovery and performance outcomes (82). Other areas of service include menu planning, food provision and travel nutrition, which play a key role in supporting optimal nutrition practices in and around competition (82). There is growing support for the role of evidence based practice within Australian sporting environments, with research identifying Australian athletes prefer sports nutrition advice and information provided by a sports nutrition professional such as a sports dietitian (71, 83). Limited access to SDs in professional sport may occur as a result of financial constraints and a lack of focus on the importance of nutrition, and can increase the likelihood of athletes receiving conflicting nutrition information from a variety of sources (71, 83-85). Research has found athletes receive nutrition advice and information from a range of sources including social media, internet, performance staff (i.e. coach, trainers, doctor), friends, and family (71, 83-85). Given that previous research has found many athletes consume suboptimal DIs and report poor NK, it is evident there is a need to provide accurate nutrition advice and education (69-71). Furthermore, positive dietary behaviours have been observed in athletes who have access to nutrition information provided by SDs (86). Hull et al. (2016) assessed the NK of collegiate athletes (n=383) and found athletes that indicated SDs as their primary nutrition information source had a better understanding of sports nutrition principles such as nutrient periodisation and were less likely to consume fast food (86). Furthermore, Hull et al. (2017) assessed and compared the dietary behaviours of collegiate baseball athletes, who had access to a sports dietitian against those who did not (87). Significant differences in dietary behaviours were found between the two groups of athletes, with those who had access to advice from SDs found to consume less fast food (P=0.02), prepared more meals at home (P=0.07) and reportedly finding it easier to consume meals before activity (P=0.03) (87). Currently there is limited research that assesses the efficacy of SDs within professional AF environments, therefore future research should aim to explore the influence of nutrition intervention on AF athletes' dietary habits and food choice (86).

2.3.4. Interpersonal Factors (i.e. relationships and social environments)

2.4.4.1. Influence of Teammates

Social connections and relationships strongly influence eating behaviours and food choice (88). Generally speaking, research has identified an individual's eating behaviours can be influenced by their external environment and food choice is often altered according to socials norms and surrounding cultures (88). Within the context of an AF environment, many athletes consume meals together, therefore social eating norms that are targeted at healthy eating including the provision of catering options planned by a sports dietitian, may positively influence eating behaviours (88).

As previously mentioned, due to limited access SDs are not always the first point of contact for nutrition information, with research finding athletes report teammates, families and friends as major sources of nutrition information. (89). In particular, young or development athletes may trust nutrition advice received from individuals within the club environment such as senior athletes, who have had personal experiences competing in sport (89). Interestingly, research by Long et al. (2011) qualitatively assessed collegiate football players personal food choice and found teammates, especially those that practiced healthy eating behaviours, were positive influences on athletes' DIs (90). Additionally, it was identified that younger athletes were more likely to alter their dietary behaviours, according to the behaviours observed by experienced athletes (90). In AF, many sports nutrition professionals may focus resources and education on young and development athletes to improve NK and food-based knowledge and skills. Currently, there is no research in AF that has explored factors that influence athletes' food choice, in particular the influence experienced and older athletes have on younger athletes meeting their nutrition goals. Therefore, to explore this phenomenon further, future research should aim to explore factors that influence AF athletes' dietary behaviours and food choices using qualitative research methods.

2.3.4.2. Influence of Family and Relationships

Motivators behind food choice such as the ones determined by individual relationships (i.e. friends and families) can determine food behaviours and influence food choice (74). Qualitative research by Heaney et al. (2008) explored barriers associated with good nutrition, finding many young athletes highlighted concerns regarding their nutrition related skills (i.e. cooking and preparation skills). Many young athletes included in this study, reported that the majority of meals consumed throughout a typical week were made by parents and/or guardians (79). Many nutrition education strategies have targeted young athletes' NK and their development of nutrition based skills (i.e. preparation, cooking, shopping), with the focus of these programs to support the transition into a professional sport environment (91). Additionally, young athletes are found to be more vulnerable to inappropriate dietary patterns which do not support performance (i.e. low or high energy dense diets to meet body composition goals and pressures) (91). With the aim to promote long term health targets, it has been highlighted in research that nutrition education for the parents and families of athletes, may be beneficial to promote food choice outside of sporting environments (79). Currently, no research has explored the effectiveness of such strategies within professional sport environments (91). Interventions in non-athletic populations have assessed the use of parent-focused nutrition education strategies and have found improved dietary behaviours such as decreased consumption of sugar-sweetened beverages (92), decreased fat intake (93, 94) and increased consumption of fruit and vegetables (93, 95) as a result. Due to existing evidence available, future research is required to explore the influence of nutrition programs that tailor education for athletes' families and to assess their effectiveness on influencing the DI behaviours of athletes. Furthermore, in order to establish tailored advice that supports dietary behaviour change, it may be beneficial to explore the influence external relationships have on AF athletes meeting nutrition goals.

2.3.5. Physiological

2.3.5.1 Appetite & Hunger

2.3.5.1.1. Influence of Exercise on Appetite Regulating Hormones

Appetite and DI are regulated by a variety of neural and hormonal signals (96). Appetite suppression experienced after moderate to high-intensity exercise, also referred as 'Exercise-induced anorexia' has been linked to changes in circulating hormones and gut motility (including delayed Gastric Emptying (GE) and reduced blood flow to the gut) and increases in core body temperature (96). Hormones such as peptide YY and glucagon-like peptide-1 (GLP-1) which are secreted by the small and large intestines, are released by the body in response to digestion and absorption and to signal satiety (i.e. cessation of appetite) (97). In comparison, the gut hormone ghrelin, is secreted by gastric cells located within the lining of the stomach and play a significant role in stimulating appetite (97). Together these hormones play key roles in regulating energy stores (97).

Although the mechanisms are not fully understood, physical activity has been found to transiently supress appetite (43, 44). It has been suggested that reduced appetite experienced post activity is a result of subsequent changes to regulating appetite hormones such as peptide YY, GLP-1 and ghrelin (96, 97). In particular, increased levels of circulating peptide YY and GLP-1 and decreased levels of ghrelin which have been observed during acute bouts of exercise are linked to appetite suppression (96). In particular, a meta-analysis that assessed acute exercise and changes in hormone levels, found after the completion of exercise, circulating ghrelin decreased by 16.5% (98). In comparison, peptide YY and GLP-1 increased by 9% and 13%, respectively (98). Growing research in this area, has identified that appetite can be suppressed from 2-10 hours post-exercise

(96, 99). However the duration of suppression will depend on the intensity of exercise undertaken, with greater rates of appetite suppression reported after completion of high-intensity outputs, in comparison to low to moderate intensities (96, 99). For example, for AF athletes during match-play and high-intensity loads observed during preseason training sessions, it is likely professional AF athletes may experience reduced appetite post physical activity. Therefore, it may be suggested that an athlete's ability to meet energy related goals in the recovery period after the completion of high-intensity physical activity, may therefore be impaired. For athletes who do experience appetite changes surrounding high-intensity training and competition, it is important that nutrition strategies (i.e. ingestion of liquid based nutrition) to overcome are considered to ensure individuals meet their recovery nutrition goals. More research is required to further understand the impact of these changes on AF athletes' DIs. It is important to note that there are a range of other factors that also contribute to changes in appetite regulation which includes fitness level, body composition and age (96, 100).

2.3.5.1.2. Influence of Exercise on Neural Signals

Appetite suppression can also be influenced by changes in neural signals such as temperature, hydration status and gastric motility (96). As detailed in Section 2.1., during an AFL season, athletes train and compete under varied conditions (i.e. high temperatures) (2). During the preseason period, athletes will undertake high-intensity training loads, which can be coupled with the inclusion of heat-specific or altitude training camps, to promote specific training adaptations (2). Physiological changes such as elevated core body temperature, GIT distress and dehydration, have been observed during high-intensity exercise and may be observed during an AF preseason training camp and competition (101). In particular, for increases in core body temperature during exercise, a cooling response in the form of sweat loss or fluid loss will occur in order to reduce an athlete's core temperature (102). A review by Charlot et al. (2017) found a decrease in energy intake and an increase in physical activity induced negative energy balance, when athletes were exposed to heat related conditions (i.e. temperatures over 20-25°C) during training and competition (103). Heat related strategies such the ingestion of cold beverages can be used to manipulate athletes' core body temperatures prior to physical activity and have been identified as a beneficial cooling strategy when athletes are exposed to hot and humid conditions (19).

Gastric Emptying (GE) during exercise has been additionally linked to changes in appetite and food intake (104). During high-intensity exercise (i.e. AF preseason and during competition) GE occurs at a slower rate in comparison to exercise at a low intensity (104). Evidence suggests potential associations between gastric distension and sensations of fullness, with reduced GE (104). Furthermore, the macronutrient content of meals before and during exercise may also influence GE rates, and will need to be considered to ensure athletes can optimise their nutrition post-exercise. However, currently the relationship between exercise-induced GE and appetite changes is inconclusive in the literature and to better understand and prevent any GIT side effects experienced during and after competition more research is required in this area (104).

2.3.6. Time

Time can be a contributing factor in food choice, with many professional athletes reporting time as a major influence on the types of foods chosen and consumed during a typical training week (90). For many athletes, rigid training and academic schedules, can create challenges when meeting their nutrition goals (90). For AF athletes, it may be suggested that challenges such as limited time to prepare food may be a factor that influences food choice, as male AF athletes train full time and many additionally undertake external study. Professional female AF athletes' intakes may also be compromise by limited time to prepare foods, with athletes training on a part-time basis, most of which occurs at night paired with study and/or work. Personal food systems of male collegiate athletes were explored by Long et al. (2011) and it was found that a greater consumption of convenience meals were reported when athletes had limited time to prepare and eat meals as a result of strict training and academic schedules (90). Furthermore, athletes included in this study reported that during busy training periods, there was a greater use of quick, microwave, and one pan meals to ensure food was consumed (90). Taken together, this research identifies the potential challenges athletes face when meeting nutrition goals and highlights the need for time effective nutrition strategies to support food choice (90).

Providing greater access to foods either via the provision of in-house catering or ready-made available meals, has been explored by research (61). In a cross-sectional research study, Devlin et al. (2016) identified that professional AF athletes consumed greater energy intakes, when compared to semi-professional AF and football athletes (61). It was identified that one of the main differences observed between professional AF and semi-professional and football programs, was that professional AF athletes had access to in-house catering (61). Therefore, it may be suggested that for athletes with busy schedules, in-house catering services may help to support athletes in meeting their nutrition goals (61). It is important to note that whilst catering may support athletes to consume higher energy intakes relative to training demands, it is important that individual taste preferences are accounted for (61, 105). Many professional AF teams (AFL) do provide catering for athletes at a range of capacities (i.e. training meals, lunch only etc.), however catering opportunities for semi-professional male and professional female athletes (AFLW) may be limited due to financial constraints. It can be suggested that access to in-house catering within high performance environments can positively influence the DIs of professional athletes, therefore greater research to support and advocate for greater access for semi-professional and professional female AF to better support optimal DIs and recovery post training, is required.

2.3.7. Conclusion

There are a variety of factors that influence athletes' food choice including 1) Psychological, 2) Nutrition knowledge and access to nutrition services, 3) Interpersonal, 4) Physiological and 5) Time (62). Factors such as support from team mates, changes in appetite post-exercise and a lack of time to prepare and cook meals have been highlighted as potential barriers to athletes meeting their nutrition goals (90, 98). This review highlights the multi-dimensional nature of food selection and the importance of specialised nutrition advice and support which can be provided by sports nutrition professionals. Currently, there is no research available that has assessed factors that influence professional AF athletes' dietary behaviours and food choice. A greater understanding of the barriers and potential challenges athletes face in meeting nutrition goals is important for the development of tailored nutrition strategies with the aim to support dietary behaviour change and to promote food choice that aligns with performance outcomes.

References

1. Ebert T. Nutrition for the Australian rules football player. Journal of Science and Medicine in Sport. 2000;3(4):82-369.
2. Johnston R, Black G, Harrison P, Murray N, Austin D. Applied Sport Science of Australian Football: A Systematic Review. Sports Medicine. 2018;48(7): 94.
3. Coutts A, Quinn J, Hocking J, Castagna C, Rampinini E. Match running performance in elite Australian rules football. Journal of Science and Medicine in Sport. 2009;13(5):8-543.
4. Gray A, Jenkins D. Match Analysis and the Physiological Demands of Australian Football. Sports Medicine. 2010;40(4):347-60.
5. Clarke A, Ryan S, Couvalias G, Dascombe B, Coutts A, Kempton T. Physical demands and technical performance in Australian Football League Women's (AFLW) competition match-play. Journal of Science and Medicine in Sport. 2018;21(7):52-748.
6. Ritchie D, Hopkins W, Buchheit M, Cordy J, Bartlett J. Quantification of Training and Competition Load Across a Season in an Elite Australian Football Club. International Journal of Sports Physiology and Performance. 2016;11(4):474.
7. Chalmers S, Magarey M, Esterman A, Speechley M, Rio E, Heynen M. The relationship between pre-season fitness testing and injury in elite junior Australian football players. Journal of Science and Medicine in Sport. 2013;16:11.
8. Bilsborough J, Kempton T, Greenway K, Cordy J, Coutts AJ. Longitudinal changes and seasonal variation in body composition in professional Australian football players. International Journal of Sports Physiology and Performance. 2017;12(1):7-10.
9. Rossignol P, Gabbett T, Comerford D, Stanton W. Repeated-Sprint Ability and Team Selection in Australian Football League Players. International Journal of Sports Physiology and Performance. 2014;9(1):161.
10. Colby M, Dawson B, Heasman J, Rogalski B, Gabbett T. Accelerometer and GPS-Derived Running Loads and Injury Risk in Elite Australian Footballers. The Journal of Strength & Conditioning Research. 2014;28(8):52.

11. Williams C, Rollo I. Carbohydrate Nutrition and Team Sport Performance. Sports Medicine. 2015;45(1):13-22.
12. Wisbey B, Rattray B, Pyne D. Quantifying changes in the AFL player game demands using GPS tracking: 2008 AFL season. AFL Board Research Report. 2008:1-36.
13. Haycraft J, Kovalchik S, Pyne D, Robertson S. Physical characteristics of players within the Australian Football League participation pathways: A Systematic Review. Sports Medicine. 2017;3(1):46.
14. Condo D, Lohman R, Kelly M, Carr A. Nutritional Intake, Sports Nutrition Knowledge and Energy Availability in Female Australian Rules Football Players. Nutrients 2019;11(5):971.
15. Bilsborough J, Greenway K, Livingston S, Cordy J, Coutts A. Changes in Anthropometry, Upper-Body Strength, and Nutrient Intake in Professional Australian Football Players During a Season. International Journal of Sport Physiology and Performance. 2016;11(3):290-300.
16. Thomas D, Erdman K, Burke L. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine and Science in Sports and Exercise. 2016;48(3):548-568.
17. Hoy D. The role of the team doctor. Feature: The role of support staff [Internet]. 2013-2014; 31(4):6-15.
18. Larkins P. Working as a sports science practitioner Feature: The role of support staff [Internet]. 2013-2014; 31(4):17.
19. Burke L. Sports Nutrition and Australian Football. International Journal of Sport Nutrition and Exercise Metabolism. 2008;18(1):8-96.
20. Bartlett J, Hatfield M, Parker B, Roberts L, Minahan C, Morton J, Thornton H. DXA-derived estimates of energy balance and its relationship with changes in body composition across a season in team sport athletes. European Journal of Sport Science. 2019:1-9.
21. Kerksick C, Wilborn C, Roberts M, Smith-Ryan A, Kleiner S, Jäger R, Collins R, Cooke M, Davis J, Galvan E, Greenwood M, Lowery L, Wildman R, Antonio J, Kreider R. ISSN exercise & sports nutrition review update: research & recommendations. Journal of the International Society of Sports Nutrition. 2018;15(1):38.

22. Jäger R, Kerksick C, Campbell B, Cribb P, Wells S, Skwiat T, Purpura M, Ziegenfuss T, Ferrando A, Arent S, Smith-Ryan A, Stout J, Arciero P, Ormsbee M, Taylor L, Wilborn C, Kalman D, Kreider R, Willoughby D, Hoffman J, Krzykowski J, Antonio J. International Society of Sports Nutrition Position Stand: Protein and exercise. Journal of the International Society of Sports Nutrition. 2017;14(1).
23. Kerksick C, Arent S, Schoenfeld B, Stout J, Campbell B, Wilborn C, Taylor L, Kalman D, Smith-Ryan A, Kreider R, Willoughby D, Arciero P, VanDusseldorp T, Ormsbee M, Wildman R, Greenwood M, Ziegenfuss T, Aragon A, Antonio J. International society of sports nutrition position stand: Nutrient timing. Journal of the International Society of Sports Nutrition. 2017;14(1).
24. Aragon A, Schoenfeld B, Wildman R, Kleiner S, VanDusseldorp T, Taylor L, Earnest C, Arciero P, Wilborn C, Kalman D, Stout J, Willoughby D, Campbell B, Arent S, Bannock L, Smith-Ryan A, Antonio J. International society of sports nutrition position stand: diets and body composition. Journal of the International Society of Sports Nutrition. 2017;14(1):16.
25. Burke L, Hawley J. Swifter, higher, stronger: What's on the menu? Science. 2018;362(6416):7-781.
26. Impey S, Hearris M, Hammond K, Bartlett J, Louis J, Close G, Morton J. Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis. Sports Medicine. 2018;48(5):1031-1048.
27. Mountjoy M, Sundgot-Borgen J, Burke L, Ackerman K, Blauwet C, Constantini N, Lebrun C, Lundy B, Melin A, Meyer N, Sherman R, Tenforde A, Klungland Torstveit M, Budgett R. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. British Journal of Sports Medicine. 2018;52(11):687-697.
28. Veale J, Pearce A, Buttifant D, Carlson J. Anthropometric Profiling of Elite Junior and Senior Australian Football Players. International Journal of Sport Physiology and Performance. 2010;5(4):509-520.
29. Gamble P. Periodization of Training for Team Sports Athletes. Strength & Conditioning Journal. 2006;28.
30. Jeukendrup A. Periodized Nutrition for Athletes. Sports Medicine. 2017;47(1):51-63.

31. Burke L, Hawley J, Jeukendrup A, Morton J, Stellingwerff T, Maughan R. Toward a Common Understanding of Diet–Exercise Strategies to Manipulate Fuel Availability for Training and Competition Preparation in Endurance Sport. International Journal of Sport Nutrition and Exercise Metabolism. 2018;28(5):451-463.
32. Routledge H, Graham S, Di Michele R, Burgess D, Erskine R, Close G, Morton J. Training Load and Carbohydrate Periodization Practices of Elite Male Australian Football Players: Evidence of Fueling for the Work Required. International Journal of Sport Nutrition and Exercise Metabolism. 2020:1-7.
33. Anderson L, Orme P, Naughton R, Close G, Milsom J, Rydings D, O'Boyle A, Di Michele R, Louis J, Hambly C, Speakman J, Morgans R, Drust B, Morton J. Energy Intake and Expenditure of Professional Soccer Players of the English Premier League: Evidence of Carbohydrate Periodization. International Journal of Sport Nutrition and Exercise Metabolism. 2017;27(3):228-238.
34. Burke L, Ross M, Garvican-Lewis L, Welvaert M, Heikura I, Forbes S, Mirtschin J, Cato L, Strobel N, Sharma A, Hawley J. Low carbohydrate, high fat diet impairs exercise economy and negates the performance benefit from intensified training in elite race walkers. Journal of Physiology. 2017;595(9):807.
35. Routledge H, Leckey J, Lee M, Garnham A, Graham S, Burgess D, Burke L, Erskine R, Close G, Morton J. Muscle Glycogen Utilisation during an Australian Rules Football Game. International Journal of Sport Physiology and Performance. 2018:1.
36. Burke L, Loucks A, Broad N. Energy and carbohydrate for training and recovery. Journal of Sports Sciences. 2006;24(7): 85.
37. Jeukendrup A. A Step Towards Personalized Sports Nutrition: Carbohydrate Intake During Exercise. Sports Medicine. 2014;44(1):25-33.
38. Bradley W, Cavanagh B, Douglas W, Donovan T, Twist C, Morton J, Close G. Energy intake and expenditure assessed 'in-season' in an elite European rugby union squad. European Journal of Sport Science. 2015;15(6): 79.
39. Longland T, Oikawa S, Mitchell C, Devries M, Phillips S. Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater

lean mass gain and fat mass loss: a randomized trial. The American Journal of Clinical Nutrition. 2016;103(3): 46.

40. Areta J, Burke L, Ross M, Camera D, West D, Broad E, Jeacocke N, Moore D, Stellingwerff T, Phillips S, Hawley J, Coffey V. Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. The Journal of Physiology. 2013;591(9): 31.

41. Macnaughton L, Wardle S, Witard O, McGlory C, Hamilton D, Jeromson S, Lawrence C, Wallis G, Tipton K. The response of muscle protein synthesis following whole-body resistance exercise is greater following 40 g than 20 g of ingested whey protein. Physiological Reports. 2016;4(15).

42. Moore D. Maximizing Post-exercise Anabolism: The Case for Relative Protein Intakes. Frontiers in Nutrition. 2019;6(147).

43. Tang J, Moore D, Kujbida G, Tarnopolsky M, Phillips S. Ingestion of whey hydrolysate, casein, or soy protein isolate: effects on mixed muscle protein synthesis at rest and following resistance exercise in young men. Journal of Applied Physiology. 2009;107(3):987-992.

44. Phillips S. Dietary protein requirements and adaptive advantages in athletes. British Journal of Nutrition. 2012;108(2):158-167.

45. Stokes T, Hector A, Morton R, McGlory C, Phillips S. Recent Perspectives Regarding the Role of Dietary Protein for the Promotion of Muscle Hypertrophy with Resistance Exercise Training. Nutrients. 2018;10(2):180.

46. Venkatraman T, Leddy T, Pendergast T. Dietary fats and immune status in athletes: clinical implications. Medicine and Science in Sport and Exercise. 2000;32(7):95-389.

47. Belski R, Forsyth A, Mantzioris E. Nutrition for sport, exercise and performance. Crows Nest, Australia: Allen & Unwin; 2019.

48. Burke L, Kiens B. "Fat adaptation" for athletic performance: the nail in the coffin? In: Burke LM, editor. 2006. p.7-8.

49. Heikura I, Uusitalo A, Stellingwerff T, Bergland D, Mero A, Burke L. Low energy availability is difficult to assess but outcomes have large impact on bone injury rates in elite

distance athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2018;28(4):403-411.

50. Holway F, Spriet L. Sport-specific nutrition: Practical strategies for team sports. Journal of Sports Sciences. 2011;29(1):115-125.

51. Kreider R, Wilborn C, Taylor L, Campbell B, Almada A, Collins R, Cooke M, Earnest C, Greenwood M, Kalman D, Kerksick C, Kleiner S, Leutholtz B, Lopez H, Lowery L, Mendel R, Smith A, Spano M, Wildman R, Willoughby D, Ziegenfuss T, Antonio J. ISSN exercise & sport nutrition review: research & recommendations. Journal of the International Society of Sports Nutrition. 2010;7(1):7.

52. Rodriguez N, Di Marco N, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. Medicine and Science in Sport and Exercise. 2009;41(3):709-731.

53. Hinton P. Iron and the endurance athlete. Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme. 2014;39(9):1080-1012.

54. National Health and Medical Research Council, New Zealand Ministry of Health. Nutrient Reference Values for Australia and New Zealand. In: Council NHMRC, editor. 2006.

55. Alaunyte I, Stojceska V, Plunkett A. Iron and the female athlete: a review of dietary treatment methods for improving iron status and exercise performance. International Journal of Sport Nutrition and Exercise Metabolism. 2015;12(1).

56. Rocha Piedade S, Imhoff A, Clatworthy M, Cohen M, Espregueira-Mendes J. Nutrition and Hydration. The Sports Medicine Physician. Cham: Springer International Publishing; 2019: 85-98.

57. O'Connell S, Woodman R, Brown I, Vincent D, Binder H, Ramakrishna B, Young G. Comparison of a sports-hydration drink containing high amylose starch with usual hydration practice in Australian rules footballers during intense summer training. Journal of the International Society of Sports Nutrition. 2018;15(1):46.

58. Burke L, Cox G. The complete guide to food for sports performance - Peak Nutrition for your Sport. Crows Nest, NSW, 2065: Allen & Unwin; 2010.

59. McCubbin A, Allanson B, Caldwell Odgers J, Cort M, Costa R, Cox G, Crawshay S, Desbrow B, Freney E, Gaskell S, Hughes D, Irwin C, Jay O, Lalor B, Ross M, Shaw G, Périard J, Burke L. Sports Dietitians Australia Position Statement: Nutrition for Exercise in Hot Environments. International Journal of Sport Nutrition and Exercise Metabolism. 2020:1-16.

60. Maughan R, Watson P, Cordery P, Walsh N, Oliver S, Dolci A, Rodriguez-Sanchez N, Galloway S. A randomized trial to assess the potential of different beverages to affect hydration status: development of a beverage hydration index. The American Journal of Clinical Nutrition. 2015;103(3):717-723.

61. Devlin B, Leveritt M, Kingsley M, Belski R. Dietary intake, body composition, and nutrition knowledge of Australian football and soccer players: Implications for sports nutrition professionals in practice. International Journal of Sport Nutrition and Exercise Metabolism. 2017;27(2):130-138.

62. Birkenhead K, Slater G. A Review of Factors Influencing Athletes' Food Choices. Sports Medicine. 2015;45(11):1511-1522.

63. Nestle M, Wing R, Birch L, DiSogra L, Drewnowski A, Middleton S, Sigman-Grant M, Sobal J, Winston M, Economos C. Behavioral and Social Influences on Food Choice. Nutrition Reviews. 1998;56(5):50-64.

64. Furst T, Connors M, Bisogni C, Sobal J, Falk L. Food Choice: A Conceptual Model of the Process. Appetite. 1996;26(3):247-266.

65. Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, Meyer N, Sherman R, Steffen K, Budgett R, Ljungqvist A. The IOC consensus statement: beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). British Journal of Sports Medicine. 2014;48(7):491-497.

66. Johnston R, Black G, Harrison P, Murray N, Austin D. Applied Sport Science of Australian Football: A Systematic Review. Sports Medicine. 2018;48(7):1673-1694.

67. Leigh Gibson E. Emotional influences on food choice: Sensory, physiological and psychological pathways. Physiology & Behavior. 2006;89(1):53-61.

68. Dallman M, Pecoraro N, Akana S, La Fleur S, Gomez F, Houshyar H, Bell M, Bhatnagar S, Laugero K, Manalo S. Chronic stress and obesity: a new view of "comfort food". Proceedings of the National Academy of Science (USA). 2003;100(20):701.
69. Trakman G, Forsyth A, Devlin B, Belski R. A Systematic Review of Athletes' and Coaches' Nutrition Knowledge and Reflections on the Quality of Current Nutrition Knowledge Measures. Nutrients. 2016;8(9):570.
70. Heaney S, O'Connor H, Michael S, Gifford J, Naughton G. Nutrition knowledge in athletes: a systematic review. International Journal of Sport Nutrition and Exercise Metabolism. 2011;21(3):248.
71. Devlin B, Belski R. Exploring General and Sports Nutrition and Food Knowledge in Elite Male Australian Athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2015;25(3):225.
72. Trakman G, Forsyth A, Hoye R, Belski R. The nutrition for sport knowledge questionnaire (NSKQ): development and validation using classical test theory and Rasch analysis. Journal of the International Society of Sports Nutrition. 2017;14:26.
73. Tam R, Beck K, Gifford J, Flood V, O'Connor H. Development of an Electronic Questionnaire to Assess Sports Nutrition Knowledge in Athletes. Journal of the American College of Nutrition. 2020:1-9.
74. Worsley A. Nutrition knowledge and food consumption: can nutrition knowledge change food behaviour? Asia Pacific Journal of Clinical Nutrition. 2002;11(3):579-585.
75. Alaunyte I, Perry J, Aubrey T. Nutritional knowledge and eating habits of professional rugby league players: does knowledge translate into practice? Journal of the International Society of Sports Nutrition. 2015;12(1):18.
76. Abood D, Black D, Birnbaum R. Nutrition Education Intervention for College Female Athletes. Journal of Nutrition Education and Behavior. 2004;36(3):135-139.
77. Valliant M, Emplaincourt H, Wenzel R, Garner B. Nutrition Education by a Registered Dietitian Improves Dietary Intake and Nutrition Knowledge of a NCAA Female Volleyball Team. Nutrients. 2012;4(6):506-516.

78. Reicks M, Trofholz A, Stang J, Laska M. Impact of Cooking and Home Food Preparation Interventions Among Adults: Outcomes and Implications for Future Programs. Journal of Nutrition Education and Behavior. 2014;46(4):259-276.
79. Heaney S, O'Connor H, Naughton G, Gifford J. Towards an Understanding of the Barriers to Good Nutrition for Elite Athletes. International Journal of Sports Science & Coaching. 2008;3(3):391-401.
80. Tam R, Beck K, Manore M, Gifford J, Flood V, O'Connor H. Effectiveness of Education Interventions Designed to Improve Nutrition Knowledge in Athletes: A Systematic Review. Sports Medicine. 2019;49(11):1769-1786.
81. Ellis J, Brown K, Ramsay S, Falk J. Changes in Student-Athletes' Self-Efficacy for Making Healthful Food Choices and Food Preparation Following a Cooking Education Intervention. Journal of Nutrition Education and Behavior. 2018;50(10):1056-1058.
82. Burkhart S, Pelly F. Beyond sports nutrition: The diverse role of dietitians at the Delhi 2010 Commonwealth Games. Journal of Human Nutrition and Dietetics. 2014;27(6):639-647.
83. Trakman G, Forsyth A, Hoye R, Belski R. Australian team sport athletes prefer dietitians, the internet and nutritionists for sports nutrition information. Nutrition and Dietetics. 2019:1-10.
84. Zuniga K, Downey D, McCluskey R, Rivers C. Need for and Interest in a Sports Nutrition Mobile Device Application Among Division I Collegiate Athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2017;27(1):43-49.
85. Shoaf L, McClellan P, Birskovich K. Nutrition knowledge, interests, and information sources of male athletes. Journal of Nutrition Education. 1986;18(6):243-249.
86. Hull M, Jagim A, Oliver J, Greenwood M, Busteed D, Jones M. Gender differences and access to a sports dietitian influence dietary habits of collegiate athletes. Journal of the International Society of Sports Nutrition. 2016;13(1).
87. Hull M, Neddo J, Jagim A, Oliver J, Greenwood M, Jones M. Availability of a sports dietitian may lead to improved performance and recovery of NCAA division I baseball athletes. Journal of the International Society of Sports Nutrition. 2017;14:29.

88. Higgs S, Thomas J. Social influences on eating. Current Opinion in Behavioral Sciences. 2016;9:1-6.

89. Eck K, Byrd-Bredbenner C. Food Choice Decisions of Athletes: Insights From Sports Dietitians. Topics in Clinical Nutrition. 2019;34(3):186.

90. Long D, Perry C, Unruh S, Lewis N, Stanek-Krogstrand K. Personal food systems of male collegiate football players: a grounded theory investigation. Journal of Athletic Training. 2011;46(6):688-695.

91. Desbrow B, McCormack J, Burke L, Cox G, Fallon K, Hislop M, Logan R, Marino N, Sawyer S, Shaw G, Star A, Vidgen H, Leveritt M. Sports Dietitians Australia Position Statement: Sports Nutrition for the Adolescent Athlete. International Journal of Sport Nutrition and Exercise Metabolism. 2014;24(5):570-584.

92. Beech B, Klesges R, Kumanyika S, Murray D, Klesges L, McClanahan B, Slawson D, Nunnally C, Rochon J, McLain-Allen B, Pree-Cary J. Child- and parent-targeted interventions: the Memphis GEMS pilot study. Ethnicity & disease. 2003;13(1):40.

93. Epstein L, Gordy CC, Raynor H, Beddome M, Kilanowski C, Paluch R. Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. Obesity research. 2001;9(3):171-178.

94. De Bourdeaudhuij I, Brug J. Tailoring dietary feedback to reduce fat intake: an intervention at the family level. Health Education Research. 2000;15(4):449-462.

95. Wardle J, Cooke L, Gibson E, Sapochnik M, Sheiham A, Lawson M. Increasing children's acceptance of vegetables a randomized trial of parent-led exposure. Appetite. 2003;40(2):155.

96. Howe S, Hand T, Manore M. Exercise-trained men and women: role of exercise and diet on appetite and energy intake. Nutrients. 2014;6(11):60.

97. Stensel D. Exercise, Appetite and Appetite-Regulating Hormones: Implications for Food Intake and Weight Control. Annals of Nutrition and Metabolism. 2010;57(2):36-42.

98. Schubert M, Sabapathy S, Leveritt M, Desbrow, B. Acute exercise and hormones related to appetite regulation: a meta-analysis. Sports Medicine. 2014;44(3):387-403.

99. Hagobian T, Yamashiro M, Hinkel-Lipsker J, Streder K, Evero N, Hackney T. Effects of acute exercise on appetite hormones and ad libitum energy intake in men and women. Applied Physiology, Nutrition, and Metabolism. 2012;38(1):66-72.

100. Martins C, Kulseng B, King N, Holst J, Blundell J. The Effects of Exercise-Induced Weight Loss on Appetite-Related Peptides and Motivation to Eat. The Journal of Clinical Endocrinology & Metabolism. 2010;95(4):1609-1616.

101. Crabtree D, Chambers E, Hardwick R, Blannin A. The effects of high-intensity exercise on neural responses to images of food. The American Journal of Clinical Nutrition. 2013;99(2):258-267.

102. Maughan R, Shirreffs S. Exercise in the heat: challenges and opportunities. Journal of Sports Sciences. 2004;22(10):917-927.

103. Charlot K, Faure C, Antoine-Jonville S. Influence of Hot and Cold Environments on the Regulation of Energy Balance Following a Single Exercise Session: A Mini-Review. Nutrients. 2017;9(6):592.

104. Horner K, Schubert M, Desbrow B, Byrne N, King N. Acute Exercise and Gastric Emptying: A Meta-Analysis and Implications for Appetite Control. Sports Medicine. 2015;45(5):659-678.

105. Pelly F, O'Connor H, Denyer G, Caterson I. Catering for the Athletes Village at the Sydney 2000 Olympic Games: The Role of Sports Dietitians. International Journal of Sport Nutrition and Exercise Metabolism. 2009;19(4):340-354.

CHAPTER THREE

3.1. Preface

Citation (3.2): Jenner S.L., Buckley G., Belski R., Devlin B., Forsyth A. Dietary intakes of professional and semi-professional team sport athletes do not meet sport nutrition recommendations—a systematic literature review. Nutrients. 2019;11(5).

Chapter two highlighted the importance of an individualised approach to nutrition which is often limited in team sport environments as a result of budget and time constraints. Previously a systematic literature review by Holway and Spriet (2011) identified that many team sport athletes consume DIs that do not align with sports nutrition recommendations, specifically for energy and CHO. A vast amount of research has been published since 2011 including updated sports nutrition recommendations. Therefore, this chapter aimed to systematically review the literature to assess the DIs of professional and semi-professional team sport athletes against recently updated sports nutrition recommendations. In addition, this review aimed to identify gaps requiring nutrition intervention. It was hypothesised that professional and semi-professional team sport athletes would consume suboptimal DIs, as per previous findings by Holway and Spriet (2011) and due that many team sport athletes have limited access to individualised nutrition advice.

nutrients

MDPI

Review

Dietary Intakes of Professional and Semi-Professional Team Sport Athletes Do Not Meet Sport Nutrition Recommendations—A Systematic Literature Review

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Abstract: Background: to develop sport-specific and effective dietary advice, it is important to understand the dietary intakes of team sport athletes. This systematic literature review aims to (1) assess the dietary intakes of professional and semi-professional team sport athletes and (2) to identify priority areas for dietetic intervention. Methods: an extensive search of MEDLINE, Sports DISCUS, CINAHL, Web of Science, and Scopus databases in April–May 2018 was conducted and identified 646 studies. Included studies recruited team sport, competitive (i.e., professional or semi-professional) athletes over the age of 18 years. An assessment of dietary intake in studies was required and due to the variability of data (i.e., nutrient and food group data) a meta-analysis was not undertaken. Two independent authors extracted data using a standardised process. Results: 21 (n = 511) studies that assessed dietary intake of team sport athletes met the inclusion criteria. Most reported that professional and semi-professional athletes' dietary intakes met or exceeded recommendations during training and competition for protein and/or fat, but not energy and carbohydrate. Limitations in articles include small sample sizes, heterogeneity of data and existence of underreporting. Conclusions: this review highlights the need for sport-specific dietary recommendations that focus on energy and carbohydrate intake. Further exploration of factors influencing athletes' dietary intakes including why athletes' dietary intakes do not meet energy and/or carbohydrate recommendations is required.

Keywords: sports nutrition; carbohydrate intake; energy; nutritional recommendations

1. Introduction

1.1. Nutrition for Team Sport Athletes

Team sports can be defined as field- and court-based sports with intermittent and high-intensity game patterns [1]. Match patterns will vary markedly among different sports and for specific positions within a sport. Team sports are divided into three categories: (1) endurance-based sports including football (i.e., soccer), Australian football, hockey (2) strength and power sports such as rugby union and league, American football and (3) batting sports such as baseball, softball and cricket [1]. Athletes participating in professional team sports are supported by high-performance and medical staff, which aim to monitor and optimise fitness, body composition and performance outcomes. The physiological demands of team sports differ and can include a range of performance modes including: running moderate to long distances, high intensity bouts of movement, variable activity patterns and small bouts of rest periods [1–3]. The variable nature of team sport exercise requires use both anaerobic and aerobic systems to fuel performance [1]. Therefore, each team sport and position within the sport, depending on the nature of training and competition, will have unique energy demands and nutrient requirements. To optimise performance and enhance recovery, international sporting committees (i.e., International Olympic Committee (IOC), American College of Sports Medicine (ACSM), International Society of Sports Nutrition (ISSN)) have provided nutrition recommendations to support dietitians working with athletes to meet their individual nutrition needs [4–9].

Dietitians must consider a range of sport-specific factors including the rules, arena size, timing of competition, frequency of matches and length of seasons (including macrocycles: preseason, competition season, off-season) when assessing an athlete's nutrition requirements and goals. Additionally, the physique characteristics and position-specific tasks of the sport will further influence the nutritional requirements of athletes. For example, the sport of rugby union will require forwards to be heavier and stronger in comparison to backs who need to be leaner and faster [10]. Due to the sport-specific factors, physique and position differences, dietary advice for team sport athletes should be individualised.

Recommendations that support athletes to consume sufficient energy and the correct balance of macronutrients and micronutrients, with appropriate timing to enhance performance and recovery, will enable athletes to train and perform optimally [11]. An earlier review by Holway and Spriet [1] found that athletes competing in team sports commonly do not meet recommended dietary intake needs [1,12]. Those that fail to consume energy and/or maintain a diet that encompasses the appropriate balance of macronutrients may find that this impedes on training adaptations and recovery [11,12]. Deficiencies in energy can have implications for an athlete's performance including a loss of fat free mass, disturbances to immune function, decreased bone mineral density, increased susceptibility to injury and increased prevalence of symptoms of overtraining [11].

1.2. Objectives

In the past decade, thousands of new research papers have been published in sports nutrition and 17 new consensus statements and recommendation papers have been released by authoritative organisations such as the IOC, ACSM, ISSN [4–9,11,13–22]. There have also been a large number of published studies on the dietary intake of professional and semi-professional team sport athletes during this time [2,3,10,23–39]. With new sports nutrition recommendations [5–8,11,13–21] and updated literature reporting the dietary intake of team sport athletes, it is now timely to review the literature to determine whether team sport athletes consume diets that align with the sports nutrition recommendations [2,3,10,23–39]. This paper aims to review the literature on dietary intakes of professional and semi-professional team sport athletes systematically with the aim of identifying priority areas for dietetic intervention.

2. Materials and Methods

2.1. Protocol Registration

All methods and search strategies were aligned with Preferred Reporting Items for Systematic Review (PRISMA) guidelines. This review was registered with International Prospective Register of Systematic Reviews (registration number: CRD42018105168) [40,41]. A PICOS criteria (i.e., Participants, Intervention, Comparison, Outcome and Study design) for review is defined in Table 1. A systematic search using terms such as sport or team sport or dietary intake or food intake was conducted by one researcher (SJ). All keywords used in search are listed in Table 2.

Table 1. Participants, Intervention, Comparison, Outcome and Study (PICOS) criteria for inclusion and exclusion of studies.

Parameter	Description
Population	Professional and semi-professional team sport athletes
Intervention OR exposure	Baseline dietary intake
Comparison	Dietary intake in comparison to sports nutrition guidelines and recommendations.
Outcomes	Meeting/not meeting sports nutrition guidelines and recommendations
Study design	RCT (where baseline dietary intake data available), cross-sectional, longitudinal, thesis (unpublished and published)

Abbreviations: RCT Randomised Control Trial.

Table 2. Table of keywords.

Concept	Keywords
Sport OR team sport	"sport*" OR "team sport*" OR "football" OR "soccer" OR "football" OR "netball" OR "AFL" OR "Aussie rules" OR "rugby" OR "basketball" OR "grid iron" OR "American football" OR "hockey"
Dietary intake OR food intake	"nutrient requirement*" OR "dietary intake" OR "daily food intake" OR "food intake"

2.2. Search Strategy

Five electronic databases including MEDLINE (Medlars International Literature Online), Sports DISCUS, CINAHL (Cumulative Index of Nursing and Allied Health Literature), Web of Science (WOS), and Scopus (World's largest abstract and citation database of peer-reviewed literature) were searched to investigate the dietary intake of professional and semi-professional team sport athletes by one researcher (SJ). The timeframe designated for the search included studies published from 2011 to present (i.e., after the 2011 review by Holway and Spriet) [1]. An additional limit regarding age (i.e., >18 years) was included to limit results to adult athletes only. In order to identify any further relevant publications, the reference lists of the studies included were hand searched and other manual searches were conducted (i.e., Google Scholar).

2.3. Eligibility Criteria

All original research (i.e., cross-sectional, longitudinal, published and unpublished thesis) conducted in adult team sport athletes (i.e., 18 years and older) and published since 2011 was considered for inclusion (Table 3). Randomised control trials were additionally included in the review if baseline dietary intake data was available. Randomised control trials where only post intervention dietary intakes were available, conference posters, abstracts and web-based articles were not included for review. Only professional and semi-professional athletes were included in the review; amateur and recreational athletes were not included. Only English-language studies were included for this review. Included studies were required to provide baseline or habitual dietary intake data that quantified energy, macronutrients and micronutrients to allow for the specified conversions made and displayed in the data extraction table i.e., energy (MJ/day), carbohydrate (grams (g) and $g \cdot kg^{-1} \cdot day^{-1}$), protein (g and $g \cdot kg^{-1} \cdot day^{-1}$), fat (g and % total energy), calcium (mg/day) and iron (mg/day). Studies that reported dietary habits, dietary knowledge, attitudes, and education strategies where dietary intake was not quantified, were excluded from the review.

Table 3. Eligibility criteria.

Inclusion	Exclusion
1. Studies that include only team sport athletes.	1. Studies that include only individual athletes or sports.
2. Studies published since 2012.	2. Studies published up to 2011.
3. Studies that include only professional or semi-professional team sport athletes.	3. Studies that include only non-professional or amateur team sport athletes.
4. Studies that include only adult team sport athletes (i.e., >18 years of age).	4. Studies that include adolescent and child team sports athletes (i.e., <18 years of age).
5. English language studies.	5. Non-English language studies.
6. Studies that include quantitative measures of dietary intake that can be converted into units of intake per day for each nutrient.	6. Studies that include nutrition habits, attitudes, educational strategies, knowledge, where dietary intakes cannot be compared.
7. Studies that include the dietary assessment of total energy carbohydrate, protein fat, micronutrient intake (i.e., iron (mg/day), calcium (mg/day), folate etc.).	7. Studies where only supplement or antioxidant intake is assessed.
8. Studies that assess dietary intake using a validated method of assessment (i.e., 7 day food diary, 7 day weighed food diary, food records, 3 day food diaries, FFQ, diet histories etc.) and therefore estimates absolute dietary intake.	8. Studies that assess dietary intake, however methods used provide dietary assessments represented in food groups, percentage of total energy etc.
9. Only human studies that include; RCT (where baseline dietary intake data available), cross-sectional, longitudinal, thesis.	9. No animal studies, RCT (where only post intervention dietary intakes available), conference posters, reviews, abstracts and web-based articles.
10. Published and unpublished research (i.e., thesis).	

Abbreviations: FFQ Food Frequency Questionnaire, RCT Randomised Control Trial.

2.4. Study Selection

All studies were screened based on title and abstract by main author (SJ). Articles deemed eligible for full text review were screened against inclusion and exclusion criteria (Table 3) by two authors (SJ and GB). Additional reviewers (AF and RB) provided advice on eligibility if a decision for inclusion and exclusion required feedback. Selection of included studies and reasons for exclusion are reported in Chart 1.

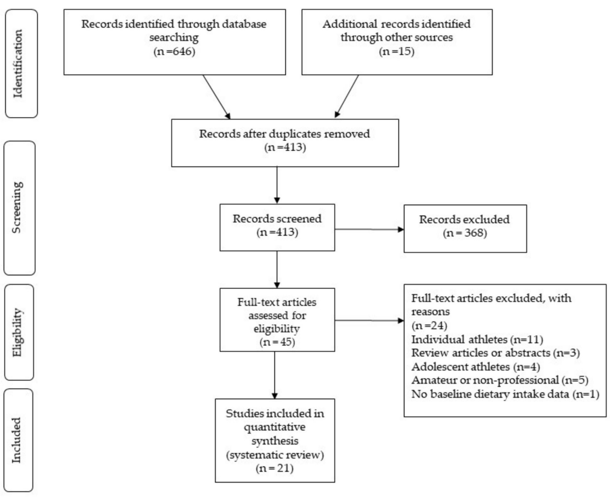

Chart 1. Study section process.

2.5. Data Collection Process

Dietary intake data were extracted from the included studies by two authors (SJ and GB). Data presented in Table 4 include participant demographics including sport, anthropometry measures (total mass (kg), body fat (%), fat free mass (kg)) and athletic level (professional or semi-professional)); details regarding the study background and methods; country of origin and survey method (i.e., 7-day food diary) and dietary intake results including total energy/calories (i.e., MJ), carbohydrate intake (i.e., g and g·kg^{-1}·day^{-1}), protein intake (i.e., g and g·kg^{-1}·day^{-1}), fat intake (i.e., g and % total energy), calcium intake (i.e., mg) and iron intake (mg). Where total energy intake was reported in calories, this was converted to MJ to enable comparison across studies.

2.6. Study Quality: Risk of Bias

The quality of studies was examined by two authors (SJ and GB) using the Academy of Nutrition and Dietetics Quality Criteria Checklist from the Academy of Nutrition and Dietetics Evidence Analysis Manual [42]. The quality criteria checklist provides an assessment based on relevance and validity criteria questions, ranking studies as either positive, neutral or negative. A third reviewer (AF) reviewed any discrepancies that occurred during the quality analysis. Studies with positive ratings needed to describe study selection adequately (including inclusion and exclusion criteria), methods of comparing groups and the study setting, and include measurements that were valid and reliable.

3. Results

3.1. Study Selection

The original search retrieved 646 studies that fit the search criteria with an additional 15 studies identified by hand searches (Chart 1). After duplicates were removed, a title and abstract exclusion was undertaken and 45 studies were retained for full text assessment. After completion of full text assessment 21 studies were included in this review for data extraction, quality assessment and analysis. All studies included in the review had a positive or neutral quality rating [41].

3.2. Study Characteristics

The majority of studies included in this review included team sport athletes competing professionally and semi-professionally in Australia (n = 255) [3,25,26,33,43] and Spain (n = 81) [28–30,36], with the remaining studies including athletes from Europe (not-specified) (n = 34) [10,27], England (n = 30) [23,34], America (n = 26) [32,38], Canada (n = 25) [39], Brazil (n = 19) [37], Netherlands (n = 14) [24], South Africa (n = 11) [35], United Kingdom (n = 10) [2], and Mexico (n = 6) [31,37]. The majority of studies included in this review reported the dietary intakes of professional team sport athletes [2,3,10,23,24,26–29,31,33,34,36,37], with additional studies exploring dietary intake of semi-professional team sport athletes [32,35,38,39] and studies exploring the dietary intakes of a combination of sports [25,30,43]. Studies included a range of team sport athletes with the majority of studies reporting on the dietary intakes of football athletes (n = 210) [23–25,28,30,31,34,37], followed by Australian football (n = 139) [3,26,43]. Across the remaining studies, other team sport athletes represented in this review include; rugby union (n = 70) [10,27,33,35], ice-hockey (n = 25) [39], wheelchair basketball (n = 17) [29], American football (n = 15) [32], handball (n = 14) [36], volleyball (n = 11) [38], rugby league (n = 10) [2].

The majority of studies included in this review used a cross-sectional study design (n = 14), with the remaining studies using pre-post-test [32,38], case-study [27,29], case control [30] and longitudinal [26,36] designs to assess dietary intake. Dietary intake data were collected most frequently using food diaries/records (weighed and not weighed). Studies used 7-day food diaries [2,3,23,28,33,35,39], 3-day food diaries [29,32,37,38] and 24 hr recalls [10,24,25,43]. Other studies used food diaries of different duration (i.e., 4-day, 6-day, and 8-day) [27,30,34], dietary recalls (i.e., 72-h) [26,36] and a combination of 4-day weighed food diary in addition to a food frequency questionnaire (FFQ) to assess dietary intake [31].

Table 4. Reported energy, macronutrient and micronutrients intakes of male and female professional and semi-professional team sport athletes.

References	Participant Characteristics							Dietary Intake Data								
Author, Year	**Sport**	**Country**	**Level**	***N* (Gender)**	**Total Mass (kg)**	**Lean Mass (kg)**	**BF%**	**Energy Intake Reported (Estimated MJ Were Available)**	**CHO (g)**	**CHO (g·kg^{-1}·day^{-1})**	**PRO (g)**	**PRO (g·kg^{-1}·day^{-1})**	**Fat (g)**	**Fat (% TE)**	**Calcium (mg·day^{-1})**	**Iron (mg·day^{-1})**	**Quality Rating**
Anderson et al. [23], (2017)	Football (soccer)	England	P	*n* = 6 (male)	80.5 ± 8.7	11.9 ± 1.2	65.0 ± 6.7	3186 ± 585 kcal·day^{-1} (13.3)	330 ± 98	4.2 ± 1.4	205 ± 30						+
Andrews and Itsiopoulus [25] (2016)	Football (soccer)	Australia	P, SP	*n* = 73 (male)	P 79.6 ± 7.7 SP 75.6 ± 7.6			P 11,525 ± 1987 kJ·day^{-1} SP 10,831 ± 3842 kJ·day^{-1} (P 11.5 ± 2.0, SP 10.8 ± 3.8)	P 302.4 ± 72.3 SP 298.7 ± 148.5	P 3.5 ± 0.8 SP 3.9 ± 1.8	P 152.3 ± 27.7 SP 149.1 ± 46.8	P 1.9 ± 0.3 SP 2.0 ± 0.6	P 95.9 ±31.7 SP 85.8 ±37.8	P 30.4 ± 7.3 SP 29.5 ± 7.4			∅
Bettonviel et al. [24] (2016)	Football (soccer)	Netherlands	P	*n* = 14 (male)	77.0 ± 8.6			2988 ± 583 kcal·day^{-1} (12.5)	365 ± 76	4.7 ± 0.7	145 ± 24	1.9 ± 0.3	97 ± 26	29.0 ± 3.6			∅
Bilsborough et al. [26] (2016)	Australian Football	Australia	P	*n* = 45 (male)	86.8 ± 7.9	[7.9 ± 1.8–10.5 ± 2.7]	[71.2 ± 6.8–76.8 ± 6.4]	[11.1–13.9]	[321 ± 142–379 ± 66]	4.1 ± 1.6	[118 ± 67–215 ± 60]	1.9 ± 0.9	[61 ± 29–110 ± 40]	[19.0 ± 5.0–33.1 ±6.7]			∅
Bradley et al. [27] (2015)	Rugby Union	Europe (non-specified)	P	*n* = 14 (male)	F 110 ± 6.2 B 93.6 ± 5.9			F 16.6 ± 1.25 MJ·day^{-1} B 14.2 ± 1.20 MJ·day^{-1}		F 3.5 ± 0.8 B 3.4 ± 0.7		F 2.7 ± 0.5 B 2.7 ± 0.3		F 32 B 33	1733 ± 694	24 ± 9	∅
Bradley et al. [10] (2015)	Rugby Union	Europe (non-specified)	P	*n* = 20 (male)	F 109.3 ± 6.9 B 91.7 ± 6.6	F 13 ± 3 B 9.3 ± 2	F 94.9 ± 4.5, B 83.1 ± 5.4	F 14.8 ± 1.9 MJ·day^{-1} B 13.3 ± 1.9 MJ·day^{-1}		F 3.3 ± 0.7 B 4.14 ± 0.4		F 2.52 ± 0.3 B 2.59 ± 0.6					∅
Conejos et al [28] (2011)	Football (soccer)	Spain	P	*n* = 22 (male)				Fwd. 12.7 ± 2.9 MJ·day^{-1} M 14.0 ± 6.2 MJ·day^{-1} D 14.8 ± 2.6 MJ·day^{-1} G 12.2 ± 4.6 MJ·day^{-1}	Fwd. 342.5± 92.9 M 382.1 ± 187.2 D 419.1 ± 98.3 G 320.3 ± 11.9		Fwd. 138.7 ± 27.5 M 144.8 ± 56.9 D 144.5 ± 19.9, G 142.8 ± 100.1		Fwd. 120.3 ± 59.6 M 131.6 ± 62.6 D 124.5 ± 36.1 G 109.8 ± 45.3	Fwd. 34.7 M 35.6 D 32.2 G 34.9	Fwd. 1361.5 ± 549.0 M 1592.3 ± 966.1 D 1208.4 ± 457.1 G 1499.7 ± 1035.9	Fwd. 13.4 ± 3.7 M 18.9 ± 9.7 D 22.6 ± 6.8 G 15.5 ± 10.2	∅
Devlin et al. [43] (2017)	Australian Football (AF) Football (Soccer, F)	Australia	P, SP	*n* = 66 AF = 48, F = 18 (male)	AF (P) 87.8 ± 9.2 AF (SP) 82.9 ± 9.0 F (P) 75.6 ± 5.6	AF (P) 15.1 ± 2.4, AF (SP) 16.7 ± 2.7 F (P) 12.8 ± 1.9	AF (P) 65.4 ± 7.9 AF (SP) 61.2 ± 3.9 F (P) 56.8 ± 5.2	AF (P) 17.3 ± 4.2 MJ·day^{-1} AF (SP) 13.2 ± 2.5 MJ·day^{-1} F (P) 9.4 ± 2.3 MJ·day^{-1}	AF (P) 406 ± 132 AF (SP) 368 ± 93 F (P) 220 ± 76	AF (P) 4.6 ± 1.5 AF (SP) 4.5 ± 1.2 F (P) 2.9 ± 1.1	AF (P) 295 ± 97 AF (SP) 171 ± 52 F (P) 140 ± 35	AF (P) 3.4 ± 1.1 AF (SP) 2.1 ± 0.7 F (P) 1.9 ± 0.5		AF (P) 29 ± 6 AF (SP) 28 ± 8 F(P) 33 ± 9			∅
Grams et al. [29] (2016)	Wheelchair basketball	Spain	P	*n* = 17 (male)	75.5 ± 13.5			2673 ± 485 kcal·day^{-1} (11.2)		3.9 [Range: 1.8–8.1]		1.7 ± 0.6		33.7 ± 5.5			+
Gravina et al. [30] (2012)	Football (soccer)	Spain	P, SP	*n* = 28 (female)	61 ± 8.4	16.7 ± 3.2		2271 ± 578 MJ·day^{-1} (9.5)						33 ± 7			+
Hidalgo et al. [31] (2015)	Football (soccer)	Mexico	P	*n* = 6 (male)	68.3 ± 2.0		32.5 ± 1.0	3042 ± 56 kcal·day^{-1} (12.7)	364 ± 17.5	5.4 ± 0.3	145 ± 14	2.2 ± 0.2	113 ± 6.3	33 ± 0.0			∅
Jenner et al. [3] (2018)	Australian Football	Australia	P	*n* = 46 (male)	86.3 ± 9.4	10.8 ± 2.3	73.9 ± 9.1	9.1 ± 1.8 MJ·day^{-1}	201 ± 56	2.4 ± 0.8	150 ± 30	1.8 ± 0.4	78.9 ± 20.0	32 ± 4.5	952 ± 287		∅
Kirwan et al. [32] (2012)	American Football	America	SP	*n* = 15 (male)	93.8 ± 15.3		70.5 ± 7.7	3518 ± 849 kcal·day^{-1} (14.7)	353 ± 118		169 ± 52		160 ± 45				∅
MacKenzie et al. [33] (2015)	Rugby Union	Australia	P	*n* = 25 (male)	100.2 ± 13.3		77.0 ± 7.0	13605 ± 3639 kJ·day^{-1} (13.6)	352 ± 115	3.6 ± 1.3	211 ± 62	2.2 ± 0.7	101 ± 34	28 ± 5.0			∅

Table 4. *Cont.*

References	Participant Characteristics							Dietary Intake Data									
Author, Year	**Sport**	**Country**	**Level**	***N* (Gender)**	**Total Mass (kg)**	**Lean Mass (kg)**	**BF%**	**Energy Intake Reported (Estimated MJ Were Available)**	**CHO (g)**	**CHO ($g \cdot kg^{-1} \cdot day^{-1}$)**	**PRO (g)**	**PRO ($g \cdot kg^{-1} \cdot day^{-1}$)**	**Fat (g)**	**Fat (% TE)**	**Calcium ($mg \cdot day^{-1}$)**	**Iron ($mg \cdot day^{-1}$)**	**Quality Rating**
Molina-lopez et al. [36] (2013)	Handball	Spain	P	*n* = 14 (male)	86.7 ± 5.4	11.6 ± 2.5		2974.5 ± 211.1 $kcal \cdot day^{-1}$ (12.4)	360.9 ± 27.6	4.2 ±0.4	133.4 ±14.3	1.5 ± 0.2	118.6 ± 22.5		1251.4 ± 338.2	24.2 ± 8.5	∅
Ono et al. [34] (2011)	Football (soccer)	England	P	*n* = 24 (male)				[2648-4606 $kcal \cdot day^{-1}$] (11.1–19.3)	505.2 ± 120		141.7 ± 22.8						∅
Potgieter, et al. [35] (2014)	Rugby Union	South Africa	SP	*n* = 11 (male)	95.5 ± 13.6	18.2 ± 5.7	79.7 ± 9.0	45.4 ± 9.0 $kcal \cdot kg^{-1} \cdot day^{-1}$		4.3 ± 0.4		2.4 ± 0.7		33.8 ± 4.3	1250 ± 403		∅
Raizel et al. [37] (2017)	Football (soccer)	Brazil	P	*n* = 19 (male)	71.8 ± 8.2	4.9 ± 1.5		40.74 ± 12.8 $kcal \cdot kg^{-1} \cdot day^{-1}$		5.4 ± 1.9	136.4 ± 57.4	1.9 ± 0.8	91.2 ± 35.9				∅
Tooley et al. [2] (2015)	Rugby League	UK	P	*n* = 10 (male)	97.3 ± 3.1			3731 ± 164 $kcal \cdot day^{-1}$ (15.6)	467 ± 24	4.9 ± 0.3	209 ± 10	2.2 ± 0.2	124 ± 10	30 ± 1.0			∅
Valliant et al. [38] (2012)	Volleyball	America	SP	*n* = 11 (female)	75.4 ± 13.4	24.5 ± 5.9		1756 ± 557.5 $kcal \cdot day^{-1}$ (7.3)	224.3 ± 64.4	3.08 ± 1.1	69.3 ± 26.8	0.9 ± 0.3	67.4 ± 27.8	33.7 ± 6.4			∅
Vermeulen et al. [39] (2017)	Ice-hockey	Canada	SP	*n* = 25 (female)	67.0 ± 1.7			2354 ± 74 $kcal \cdot day^{-1}$ (9.8)	305 ± 15	4.6 ± 0.2	91 ± 4	1.4 ± 0.1	82 ± 4	32 ± 1.0	1041 ± 64	19 ± 3	∅

Abbreviations: AF Australian Football, F Football (soccer), BF% Body fat percentage, CHO Carbohydrate, D Defenders, Fwd Forwards, GK Goal-keepers, $kcal \cdot day^{-1}$ Calories per day, $Kcal \cdot kg^{-1} \cdot day^{-1}$ Calories per kg per day, $kJ \cdot day^{-1}$ Kilojoules per day, $MJ \cdot day^{-1}$ Mega joules per day, M Midfielders *PRO* Protein, *P* Professional, *SP* Semi-professional. Quality rating criteria: Positive (+), Neutral (∅) and Negative (−).

3.3. Dietary Intake of Team Sport Athletes

3.3.1. Energy Intake of Team Sport Athletes on Training Days

All studies included assessed the energy intake of team sport athletes. The majority of authors assessed the energy intake of athletes against recommendations advocated by IOC, ACSM, ISSN and sports specific research [1,4,12,35,44–55]. Several studies provided evidence that energy intake of team sport athletes assessed was suboptimal and did not meet recommendations [2,3,10,26,28,35,36,38]. Of the 21 studies included, five studies reported that energy intake was adequate according to the respective dietary recommendations used [23,32,33,37,39]. One study by Devlin et al. [43] reported that the Australian football athletes included met energy recommendations, however the football athletes did not. The remaining studies (n = 7) did not report on adequacy of energy intake (i.e., recommendations met versus not met) [24,25,27,29–31,34].

3.3.2. Energy Intake of Team Sport Athletes during Competition

The mean energy intake reported in this review ranged from 9.1–16.6 MJ/day and 7.3–9.8 MJ/day for males and females respectively. Seven studies included comparison data of dietary intake on training days and match days [2,23,24,27,31,35,39]. Two studies that explored the dietary intake of rugby union (n = 10) and ice hockey (n = 25) athletes on match days found that energy intake did not meet increased requirements for the fueling and recovery required on match days [2,39]. However, in comparison, two studies that included professional rugby union (n = 14) and football athletes (n = 6), found that energy intake was greater on match days in comparison to training days [23,27]. In particular, research by Bradley et al. [27] found that on average professional rugby union athletes increased their energy intake in preparation for game day in comparison to the first four days of training where energy intake was reduced, irrespective of energy expenditure. Anderson et al. [23] additionally found that professional football players (n = 6) had a greater absolute and relative energy intake on match days in comparison to training days.

3.3.3. Macronutrient Intake of Team Sport Athletes on Training Days

Overall, the macronutrient composition of the diets of team sport athletes was inadequate to meet the fuel, recovery and performance demands of their sports. All but one study assessed the dietary intake of carbohydrate and protein [30] and all but two assessed the dietary intake of fat [30,34]. Overall, a macronutrient imbalance was found in the majority of studies with most athletes reported consuming diets high in protein and fat, at the expense of carbohydrate. Team sport athletes including athletes from football (n = 175), Australian football (n = 139), rugby union (n = 88), volleyball (n = 11) and rugby league (n = 10) consumed diets that consistently did not meet carbohydrate recommendations [2,3,10,23–28,30,33,35–38,43]. Out of the 17 studies that provided mean intakes of carbohydrates, 15 reported low carbohydrate intake and fell below ISSN recommended intakes of 5-8 $g \cdot kg^{-1} \cdot day^{-1}$ (range: 2.4–4.9 $g \cdot kg^{-1} \cdot day^{-1}$ and 3.08–4.6 $g \cdot kg^{-1} \cdot day^{-1}$ for male and female athletes respectively). One study that explored the dietary intakes of male professional football players found that carbohydrate intakes consumed by athletes were closer to meeting recommendations for tactical or skill based sports (3–5 $g \cdot kg^{-1} \cdot day^{-1}$) [12,25].

Conversely, the majority of studies found that dietary intake of protein [2,10,24–26,28,30,31,33,35–37,43,56] and fat [24,27,28,32,35–37] exceeded recommendations. Eight studies that included athletes competing professionally and semi-professionally in Australian football, rugby league, rugby union and football found protein intakes in excess of 2.0 $g \cdot kg^{-1} \cdot day^{-1}$ [2,10,25,27,31,33,35,43], with a study reporting that the diets of professional Australian football athletes on average contained 3.4 ± 1.1 $g \cdot kg^{-1} \cdot day^{-1}$ of protein per day [43]. Studies included in this review reported dietary intakes that were high in protein, however low in carbohydrates and/or total energy (hypocaloric) [2,3,10,26,28,35,36,38,43]. Nine studies found that dietary intake of fat exceeded recommendations [2,27–29,31,32,35,37,39]. Three studies that included rugby union athletes (n = 35) and football athletes

(n = 25) found that while overall total fat intake exceeded recommendations, polyunsaturated fat intake fell below recommended intakes of 10% of total energy [31,35,37]. Six studies explored the intake of cholesterol, finding that dietary intakes of athletes exceeded recommended intakes of <300 mg/day [2,28,31,32,35,37]. Kirwan et al. [32] linked high cholesterol intakes to potential body composition goals of American football athletes (i.e., to put on mass, quickly).

3.3.4. Macronutrient Intake of Team Sport Athletes during Competition

Three of seven studies that assessed intake on competition days found that carbohydrate consumed in preparation for match day, during the match and during the recovery period post game, did not meet recommended intakes for competitions [24,31,39]. One study in female ice-hockey players found that there was no significant difference in carbohydrate, protein and fat intakes between game, training and rest days [39]. In comparison, three studies on rugby union (2) and football (1) athletes found that carbohydrate intake during and post-game day met recommendations [23,27,35]. In particular, Anderson et al. [23] found that athletes practiced a level of periodization, finding that carbohydrate consumed on the two match days were significantly greater than carbohydrate consumed on training days (p = < 0.05; 6.4 g·kg^{-1}·day^{-1} and 4.2 g·kg^{-1}·day^{-1} for match and training days respectively). In comparison, research by Bettonviel et al. [24] found that professional football players as a whole failed to meet carbohydrate recommendations on match days (5.3 ± 1.5 g·kg^{-1}·day^{-1}) and one day post-match (4.5 ± 1.0 g·kg^{-1}·day^{-1}); however, protein intakes on match day and post-match were adequate (2.0 ± 0.4 and 1.6 ± 0.3 g·kg^{-1}·day^{-1} respectively).

3.3.5. Micronutrient Intake

Six studies reported iron and/or calcium intakes [3,27,28,35–37,39]. The majority of these studies found that team sport athletes were meeting or exceeding recommended intakes of calcium and iron, when compared to the general public [27,28,35,36,39]. One study by Raizel et al. [37] found that professional football players were not meeting general (non-sport specific) recommendations (estimated average requirements) for calcium, reporting that athletes had a marginal intake of 83% of EAR.

4. Discussion

4.1. Energy Intake of Team Sport Athletes

In order for athletes to optimise training and performance, they need to consume sufficient energy for the work required and to support physiological adaptions [11,13,57]. A diet that contains insufficient energy (i.e., energy deficit) during periods of training can result in a number of performance detriments including loss of lean muscle mass and bone mineral density, increased prevalence of overtraining and injury, and may contribute to endocrine and reproductive system disturbances [11]. The mean energy intakes of professional male team sport athletes reported in the literature have decreased from those reported by a previous review [1]; however, in comparison female athletes are consuming diets of relatively similar energy density (i.e., 7.3–9.8 MJ/day) [1]. Simply looking at the difference in energy intakes of male team athletes would suggest that they are eating less and potentially not meeting energy recommendations; however, a range of factors may have influenced the dietary intake of these athletes at the time of assessment.

While not identified as an influencing factor previously [1], three studies included in this review that explored the dietary intakes of rugby union, Australian football and football athletes suggested that low energy intakes were related to the presence of team culture surrounding body composition goals (i.e., to decrease body fat and/or increase lean muscle mass) [3,10,25]. In theory, body composition goals should be individualised to the athlete, with the focus to support training adaptions; however, this is not always reflected in practice [8]. Research by Bradley et al. [10] found that during a rugby union preseason, athletes did not meet energy intake recommendations (14.8 ± 1.9 MJ/day) and it was found that the existence of body composition goals (i.e., to reduce body fat) were potentially influencing intake at the expense of fueling for training demands. Research during a preseason in Australian football, hypothesised that athletes intentionally restricted energy and carbohydrate intake surrounding body composition assessments using dual-energy X-ray absorptiometry (DXA), to meet target body composition goals (actual energy intake: 9.1 ± 1.8 MJ/day) [3]. Similarly, Andrews et al. [25] reported professional and semi-professional football athletes that were recognised as under reporters were those athletes that were identified as attempting to maintain body composition or reduce body fat at the time of recording (11.5 ± 2.0 and 10.8 ± 3.8 MJ/day). Realistic body composition goals must be promoted to prevent under fueling and support the training adaptions and recovery of athletes. Furthermore, in light of recent research regarding relative energy deficiency (RED-S) in male athletes, there is a greater need for education for coaches and support staff regarding the importance of an individualised approach when tailoring body composition goals [8].

4.2. Macronutrient Intake of Team Sport Athletes

4.2.1. Carbohydrate Intake of Team Sport Athletes

Carbohydrate intake is important for optimising performance and recovery. Team sports have varied training and physiological demands, therefore advice must be tailored to match the training demands as well as the demands of specific positions within the sport. Team sport athletes included in this review continue to consume diets that do not align with carbohydrate recommendations, intakes on average insufficient when compared to recommendations [1,11,12,52]. Research included has suggested that carbohydrate recommendations need to be better suited to the demands of the sport, individualising nutrition based on positions [10,23,28,58]. Research by Bradley et al. [27] found that professional rugby union athletes tapered carbohydrate intake across a training week; however, on average intakes fell below recommendations used by authors of 6–10 $g{\cdot}kg^{-1}{\cdot}day^{-1}$ (3.5 $g{\cdot}kg^{-1}{\cdot}day^{-1}$ and 3.4 $g{\cdot}kg^{-1}{\cdot}day^{-1}$ for forwards and backs respectively). Although these intakes did not align with recommendations, Bradley et al. [27] suggested that the tapering of intakes during a training week to match demands of training as well as enhance training adaptions (i.e., alter body fat) may be better suited to this athletic population. The idea of "*fueling for the work required*" is commonly being used by many sports nutrition professionals working in professional sport [59]. The concept of periodising intake is not simple and requires thorough knowledge of the athlete's needs, the sport and the training and competition demands. Anderson et al. [23] found that football athletes were applying the principle of carbohydrate periodization to their daily intakes; consuming significantly greater energy and carbohydrate on game days compared to training days. However, when assessing dietary intakes as a whole; carbohydrate intake the day before a competition was unlikely to maximise glycogen storage and, therefore, meet match demands. Dietitians working with professional team sport athletes need to use an individualised approach when periodising an athlete's carbohydrate intake. Further work is required to support education in this space to optimise glycogen storage and resynthesis and to support athletes' training and match day nutrition goals.

4.2.2. Protein Intake of Team Sport Athletes

Protein is important for muscle protein synthesis, supports recovery processes, promotes satiety and can aid the maintenance of body composition. It also has many other important roles in the body as enzymes, hormones, transporters and antibodies. Athletes with insufficient protein intakes have an increased risk of muscle wasting, illness and injury. ISSN recommendations state that to maintain protein balance athletes should consume 1.4–2.0 $g{\cdot}kg^{-1}{\cdot}day^{-1}$ of high-quality protein [11]. In this review team sport athletes, on average, adequately met recommendations; most athletes adopting a diet high in protein, but low in carbohydrates and/or total energy (hypocaloric) [2,3,10,26,28,35,36,38,43]. Research has suggested that high-protein diets (2.3–3.1 $g{\cdot}kg^{-1}{\cdot}day^{-1}$) may be appropriate for resistance trained athletes who are consuming hypocaloric diets with the aim to maintain lean muscle tissue while reducing fat mass [20,60]. This is supported by research by Bradley et al. [10] who found that although protein intakes of professional rugby athletes (2.5–2.6 g·kg^{-1}·day^{-1}) exceeded protein recommendations, since athletes were manipulating carbohydrate intakes during the preseason training week, protein intakes may have been appropriate at the time to optimise body composition. Given the context of the time of season this study was undertaken (i.e., preseason) and the ability for athletes to optimise training adaptions and changes to body composition without any detriment to competition performance, these intakes may be acceptable for this athletic cohort. However, in contrast, research by Potgieter et al. [35] reported that rugby union athletes' intakes in-season did not meet carbohydrate recommendations, and exceeded protein recommendations. Potgieter et al. [35] suggests that greater intakes of protein (i.e., 2.4 g·kg^{-1}·day^{-1}) may be suited in times where muscle hypertrophy is required (i.e., offseason); however, in-season where athletes are required to meet training, competition and recovery demands, protein intakes should align with recommendations and not be increased at the expense of carbohydrate intake. Similarly, research by Mackenzie et al. [33] on rugby union athletes reported that there was no compelling evidence to increase the distribution of protein for muscle protein synthesis and that an excess quantity of protein may in fact compromise lean muscle goals by promoting satiety which can result in decreased calorie intake. Taken as a whole, when working with team sport athletes greater emphasis should be placed on the distribution and timing of protein intake across a training day, instead of the total quantity [33]. In addition, it should be highlighted that the need to meet a body composition goal should not come at the expense of meeting nutrient requirements for performance and recovery.

4.2.3. Fat Intake of Team Sport Athletes

Four of the studies that reported athletes' diets exceeding recommended fat intakes (i.e., >30% of total energy) included the dietary intakes of athletes competing in strength and power sports such as rugby union (2), rugby league (1) and American football (1) [2,27,32,35]. Collectively strength and power sports are characterised as high-intensity and intermittent collision sports and may require a greater total mass to protect athletes against the physical impacts of scrumming, tackling etc. [1,2,27,32,35]. A study that explored the dietary intakes of American football athletes found that athletes consumed high intakes of fat (i.e., 41% of total energy) suggesting these intakes were a result of overfeeding to increase weight [32]. In comparison, research by Bradley et al. [27] in rugby union found that athletes had fat intakes that fell slightly above recommendations (i.e., 32% and 33% for forwards and backs respectively); however, in contrast they had suboptimal total energy intake when compared to energy expenditure. Additionally Potgieter et al. [35] found that competing rugby union athletes were consuming an excess in fat (i.e., 33.8 ± 4.3%), however failed to meet recommendations for total energy and carbohydrate. Taken together, these results indicate a reduction in dietary fat intake for these groups may not be warranted in order to support athletes to meet energy requirements. However, as many athletes did not meet these enhanced energy requirements, the addition of carbohydrate may allow athletes to meet energy balance or surplus, without the need for intakes that are in excess of dietary fat.

Although most team sport athletes included in this review consumed diets that were in line with or exceeded recommendations for dietary fat intake, the composition of saturated to unsaturated fats (i.e., mono and poly unsaturated fats) was suboptimal (i.e., saturated fat >10% total energy). This is supported by Hidalgo et al. [31] who found that football players' total dietary fat intake aligned with recommendations (i.e., 30%–33% of total energy); however, saturated fat and cholesterol intake exceeded recommendations. In addition, it was found that polyunsaturated fat intake fell below recommended intakes. Hidalgo et al. [31] and Raizel et al. [37] together suggested that football athletes' high protein intake, including a large intake of animal proteins, may have contributed to their overall high cholesterol intake. Research suggests diets that are rich in saturated fat (i.e., >10%TE), cholesterol and trans fats are linked to chronic diseases such as cardio-vascular disease (i.e., heart disease and stroke) and type 2 diabetes [61]. For the long term health of athletes, dietary advice should aim to include a varied diet with a focus on total and saturated fat, not exceeding recommendations (i.e., total fat <30% total energy and saturated fat <10% total energy) [11]. Additionally, athletes may benefit from the inclusion of mono- and poly unsaturated fat-based protein foods (i.e., fatty fish, nuts and seeds) to help meet energy and protein requirements and provide additional anti-inflammatory benefits for training and recovery [22].

This review highlights the role of dietitians in providing long-term dietary strategies to increase lean muscle and total body mass, in a manner that does not adversely affect performance and/or lipid profile, which may be evident in short term high energy and high fat diets. Greater education regarding the long-term implications of intakes that are in excess of total fat and saturated fat is required in team sport environments.

4.2.4. Dietary Intake during Competition

Due to the elevated requirements for stored glycogen and glycogen resynthesis during training and competition, athletes are recommended to undertake aggressive carbohydrate feeding prior to these periods. Inconsistencies between energy and carbohydrate intakes on training and match days were observed in team sport athletes. In particular research by Bettonviel et al. [24] found that carbohydrate intakes of football athletes did not meet recommendations (6–10 $g \cdot kg^{-1} \cdot day^{-1}$) for match days; however, in comparison these athletes exceeded recommended protein intakes. Additionally, research by Potgieter et al. [35] found that while rugby union athletes were consuming adequate energy and carbohydrate prior to competition, diets were additionally high in protein and fat. Interestingly, research by Tooley et al. [2] found that rugby league athletes had greater fat intakes on the two days post competition (i.e., "recovery period"). This research suggested that this elevated intake of fat might be considered a 'reward' post competition for these athletes [2,62]. Greater education on match day nutrition strategies are required to optimise energy and carbohydrate intake prior to competition. Additionally, in many sports athletes need to compete multiple times a week therefore it is integral that recovery tactics aim to restore muscle glycogen within 24–48 h post-competition [57]. In these instances, it is essential to consume a carbohydrate and protein-rich meal shortly after the game, followed by another carbohydrate-rich meal two hours later to accelerate glycogen resynthesis [11].

4.3. Limitations

Studies in this systematic review included small numbers of participants and may not be generalisable to team sport disciplines more broadly. In addition, the heterogeneity of the included studies led to an inability to compare results across all studies and as a result a meta-analysis of data was not possible. Underreporting is an important consideration when assessing dietary intake; however, suboptimal intakes should not be attributed solely to underreporting and dietary assessment should encompass a range of influencing factors (i.e., body composition, appetite, nutrition knowledge etc.) [3]. Many studies explored the existence of intentional and unintentional underreporting, thus the findings of these analyses should be interpreted with caution.

4.4. Conclusions

This systematic review found that despite the publication of high-quality research studies, expert consensus statements and recognition of the consequences of inadequate intakes, team sport athletes' total energy and carbohydrate intakes did not meet sports nutrition recommendations (i.e., IOC, ISSN, ASCM and sports specific research) for energy and carbohydrate. In contrast, many athletes met or exceeded recommendations for protein and/or fat. Further research into the development of sport-specific recommendations for energy and macronutrients in particular carbohydrate would be beneficial to further optimise distribution throughout a training week. Furthermore, nutrition in team sport environments requires a knowledge base of the physiological demands of training and competition, and therefore sports dietitians should work collaboratively with sports science teams when tailoring nutrition advice to meet energy and macronutrient needs. Future research is required to explore the factors that influence athletes' dietary intakes.

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References

1. Holway, F.E.; Spriet, L.L. Sport-specific nutrition: Practical strategies for team sports. *J. Sports Sci.* **2011**, *29*, S115–S125. [CrossRef] [PubMed]
2. Tooley, E.; Bitcon, M.; Briggs, M.A.; West, D.J.; Russell, M. Estimates of energy intake and expenditure in professional rugby league players. *Int. J. Sports Sci. Coach.* **2015**, *10*, 551–560. [CrossRef]
3. Jenner, S.L.; Trakman, G.; Coutts, A.; Kempton, T.; Ryan, S.; Forsyth, A.; Belski, R. Dietary intake of professional Australian football athletes surrounding body composition assessment. *J. Int. Soc. Sports Nutr.* **2018**, *15*, 43. [CrossRef] [PubMed]
4. Rodriguez, N.R.; Dimarco, N.M.; Langley, S. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. *J. Am. Diet. Assoc.* **2009**, *109*, 509–527. [CrossRef] [PubMed]
5. Potgieter, S. Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American college of sport nutrition, the International Olympic Committee and the international society for sports nutrition. *S. Afr. J. Clin. Nutr.* **2013**, *26*, 6–16. [CrossRef]
6. Kerksick, C.M.; Arent, S.; Schoenfeld, B.J.; Stout, J.R.; Campbell, B.; Wilborn, C.D.; Taylor, L.; Kalman, D.; Smith-Ryan, A.E.; Kreider, R.B.; et al. International society of sports nutrition position stand: Nutrient timing. *J. Int. Soc. Sports Nutr.* **2017**, *14*, 33. [CrossRef] [PubMed]
7. Aragon, A.A.; Schoenfeld, B.; Wildman, R.; Kleiner, S.; Vandusseldorp, T.; Taylor, L.; Earnest, C.P.; Arciero, P.J.; Wilborn, C.; Kalman, D.S.; et al. International society of sports nutrition position stand: diets and body composition. *J. Int. Soc. Sports Nutr.* **2017**, *14*, 16. [CrossRef]
8. Mountjoy, M.; Sundgot-Borgen, J.; Burke, L.; Ackerman, K.E.; Blauwet, C.; Constantini, N.; Lebrun, C.; Lundy, B.; Melin, A.; Meyer, N.; et al. International Olympic Committee (IOC) consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Int. J. Sport Nutr. Exerc. Metab.* **2018**, *28*, 316–331. [CrossRef]
9. International Olympic Committee. IOC consensus statement on sports nutrition 2010. *Int. J. Sport Nutr. Exerc. Metab.* **2010**, *1003*. [CrossRef]
10. Bradley, W.J.; Cavanagh, B.P.; Douglas, W.; Donovan, T.F.; Morton, J.P.; Close, G.L. Quantification of training load, energy intake, and physiological adaptations during a rugby preseason: A case study from an elite european rugby union squad. *J. Strength Cond. Res.* **2015**, *29*, 534–544. [CrossRef]
11. Kerksick, C.M.; Wilborn, C.D.; Roberts, M.D.; Smith-Ryan, A.; Kleiner, S.M.; Jäger, R.; Collins, R.; Cooke, M.; Davis, J.N.; Galvan, E.; et al. ISSN exercise & sports nutrition review update: research & recommendations. *J. Int. Soc. Sports Nutr.* **2018**, *15*, 38. [CrossRef] [PubMed]
12. Burke, L.M.; Hawley, J.A.; Wong, S.H.; Jeukendrup, A.E. Carbohydrates for training and competition. *J. Sports Sci.* **2011**, *29*, S17–S27. [CrossRef]
13. Thomas, D.T.; Erdman, K.A.; Burke, L.M. American college of sports medicine joint position statement. nutrition and athletic performance. *Med. Sci. Sports Exerc.* **2016**, *48*, 543–568. [CrossRef] [PubMed]
14. Kreider, R.B.; Kalman, D.S.; Antonio, J.; Ziegenfuss, T.N.; Wildman, R.; Collins, R.; Candow, D.G.; Kleiner, S.M.; Almada, A.L.; Lopez, H.L. International Society of Sports Nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine. *J. Int. Soc. Sport Nutr.* **2017**, *14*, 18. [CrossRef] [PubMed]

15. Wilson, J.M.; Fitschen, P.J.; Campbell, B.; Wilson, G.J.; Zanchi, N.; Taylor, L.; Wilborn, C.; Kalman, D.S.; Stout, J.R.; Hoffman, J.R.; et al. International Society of Sports Nutrition Position Stand: beta-hydroxy-beta-methylbutyrate (HMB). *J. Int. Soc. Sport Nutr.* **2013**, *10*, 6. [CrossRef]
16. Campbell, B.; Wilborn, C.; La Bounty, P.; Taylor, L.; Nelson, M.; Greenwood, M.; Ziegenfuss, T.N.; Lopez, H.L.; Hoffman, J.R.; Stout, J.R.; et al. International Society of Sports Nutrition position stand: energy drinks. *J. Int. Soc. Sports Nutr.* **2013**, *10*, 1. [CrossRef]
17. Maughan, R.J.; Burke, L.M.; Dvorak, J.; Larson-Meyer, D.E.; Peeling, P.; Phillips, S.M.; Rawson, E.S.; Walsh, N.P.; Garthe, I.; Geyer, H.; et al. IOC Consensus Statement: Dietary Supplements and the High-Performance Athlete. *Int. J. Sport Nutr. Exerc. Metab.* **2018**, *28*, 104–125. [CrossRef] [PubMed]
18. Bergeron, M.F.; Bahr, R.; Bärtsch, P.; Bourdon, L.; Calbet, J.A.; Carlsen, K.H.; Castagna, O.; González-Alonso, J.; Lundby, C.; Maughan, R.J.; et al. International Olympic Committee consensus statement on thermoregulatory and altitude challenges for high-level athletes. *Br. J. Sports Med.* **2012**, *46*, 770–779. [CrossRef] [PubMed]
19. Trexler, E.T.; Smith-Ryan, A.E.; Stout, J.R.; Hoffman, J.R.; Wilborn, C.D.; Sale, C.; Kreider, R.B.; Jäger, R.; Earnest, C.P.; Bannock, L.; et al. International society of sports nutrition position stand: Beta-Alanine. *J. Int. Soc. Sports Nutr* **2015**, *12*, 30. [CrossRef] [PubMed]
20. Jäger, R.; Kerksick, C.M.; Campbell, B.I.; Cribb, P.J.; Wells, S.D.; Skwiat, T.M.; Purpura, M.; Ziegenfuss, T.N.; Ferrando, A.A.; Arent, S.M.; et al. International Society of Sports Nutrition Position Stand: Protein and exercise. *J. Int. Soc. Sports Nutr.* **2017**, *14*, 20. [CrossRef]
21. Position of the Academy of Nutrition and Dietetics. Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *Can. J. Diet. Pract. Res.* **2016**, *77*, 54. [CrossRef] [PubMed]
22. Kreider, R.B.; Wilborn, C.D.; Taylor, L.; Campbell, B.; Almada, A.L.; Collins, R.; Cooke, M.; Earnest, C.P.; Greenwood, M.; Kalman, D.S.; et al. ISSN exercise & sport nutrition review: Research & recommendations. *J. Int. Soc. of Sports Nutr.* **2010**, *7*, 7. [CrossRef]
23. Anderson, L.; Orme, P.; Naughton, R.J.; Close, G.L.; Milsom, J.; Rydings, D.; O'Boyle, A.; Di Michele, R.; Louis, J.; Hambly, C.; et al. Energy Intake and Expenditure of Professional Soccer Players of the English Premier League: Evidence of Carbohydrate Periodization. *Int. J. Sport Nutr. Exerc. Metab.* **2017**, *27*, 228–238. [CrossRef] [PubMed]
24. Bettonviel, A.E.O.; Brinkmans, N.Y.J.; Russcher, K.; Wardenaar, F.C.; Witard, O.C. Nutritional Status and Daytime Pattern of Protein Intake on Match, Post-Match, Rest and Training Days in Senior Professional and Youth Elite Soccer Players. *Int. J. Sport Nutr. Exerc. Metab.* **2016**, *26*, 285–293. [CrossRef]
25. Andrews, M.C.; Itsiopoulos, C. Room for improvement in nutrition knowledge and dietary intake of male football (Soccer) players in Australia. *Int. J. Sport Nutr. Exerc. Metab.* **2016**, *26*, 55–64. [CrossRef]
26. Bilsborough, J.C.; Greenway, K.; Livingston, S.; Cordy, J.; Coutts, A.J. Changes in anthropometry, upper-body strength, and nutrient intake in professional Australian football players during a season. *Int. J. Sports Physiol. Perform.* **2016**, *11*, 290–300. [CrossRef] [PubMed]
27. Bradley, W.J.; Cavanagh, B.; Douglas, W.; Donovan, T.F.; Twist, C.; Morton, J.P.; Close, G.L. Energy intake and expenditure assessed 'in-season' in an elite European rugby union squad. *Eur. J. Sport Sci.* **2015**, *15*, 469–479. [CrossRef]
28. Conejos, C.; Giner, A.; Mañes, J.; Soriano, J.M. Energy and nutritional intakes in training days of soccer players according to their playing positions. *Arch. Med. Deporte* **2011**, *28*, 29–35.
29. Grams, L.; Garrido, G.; Villacieros, J.; Ferro, A. Marginal Micronutrient Intake in High-Performance Male Wheelchair Basketball Players: A Dietary Evaluation and the Effects of Nutritional Advice. *PLoS ONE* **2016**, *11*, e0157931. [CrossRef]
30. Gravina, L.; Ruiz, F.; Diaz, E.; Lekue, J.A.; Badiola, A.; Irazusta, J.; Gil, S.M. Influence of nutrient intake on antioxidant capacity, muscle damage and white blood cell count in female soccer players. *J. Int. Soc. Sports Nutr.* **2012**, *9*, 32. [CrossRef]
31. Hidalgo y Teran Elizondo, R.; Martin Bermudo, F.M.; Penaloza Mendez, R.; Berna Amoros, G.; Lara Padilla, E.; Berral de la Rosa, F.J. Nutritional intake and nutritional status in elite Mexican teenagers soccer players of different ages. *Nutr. Hosp.* **2015**, *32*, 1735–1743. [CrossRef]
32. Kirwan, R.D.; Kordick, L.K.; McFarland, S.; Lancaster, D.; Clark, K.; Miles, M.P. Dietary, anthropometric, blood-lipid, and performance patterns of American college football players during 8 weeks of training. *Int. J. Sport Nutr. Exerc. Metab.* **2012**, *22*, 444–451. [CrossRef]

33. MacKenzie, K.; Slater, G.; King, N.; Byrne, N. The measurement and interpretation of dietary protein distribution during a rugby preseason. *Int. J. Sport Nutr. Exerc. Metab.* **2015**, *25*, 353–358. [CrossRef]
34. Ono, M.; Kennedy, E.; Reeves, S.; Cronin, L. Nutrition and culture in professional football. A mixed method approach. *Appetite* **2012**, *58*, 98–104. [CrossRef]
35. Potgieter, S.; Visser, J.; Croukamp, I.; Markides, M.; Nascimento, J.; Scott, K. Body composition and habitual and match-day dietary intake of the FNB Maties Varsity Cup rugby players.(ORIGINAL RESEARCH). *S. Afr. J. Sports Med.* **2014**, *26*, 35–43. [CrossRef]
36. Molina-López, J.; Molina, J.M.; Chirosa, L.J.; Florea, D.; Sáez, L.; Jiménez, J.; Planells, P.; Perez de la Cruz, A.; Planells, E. Implementation of a nutrition education program in a handball team; consequences on nutritional status. *Nutr. Hosp.* **2013**, *28*, 1065–1076. [CrossRef]
37. Raizel, R.; da Mata Godois, A.; Coqueiro, A.Y.; Voltarelli, F.A.; Fett, C.A.; Tirapegui, J.; de Paula Ravagnani, F.C.; de Faria Coelho-Ravagnani, C. Pre-season dietary intake of professional soccer players. *Nutr. Health* **2017**, *23*, 215–222. [CrossRef]
38. Valliant, M.W.; Pittman Emplaincourt, H.; Wenzel, R.K.; Garner, B.H. Nutrition Education by a Registered Dietitian Improves Dietary Intake and Nutrition Knowledge of a NCAA Female Volleyball Team. *Nutrients* **2012**, *4*, 506–516. [CrossRef] [PubMed]
39. Vermeulen, T. Seven Day Dietary Intakes of Female Varsity Ice Hockey Players. Master's Thesis, The University of Guelph, Guelph, ON, Canada, 2017.
40. International Prospective Register of Systematic Reviews. Available online: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=105168 (accessed on 24 September 2018).
41. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA statement. *Ann. Intern. Med.* **2009**, *151*, 264–269. [CrossRef] [PubMed]
42. Academy of Nutrition and Dietetics. Evidence Analysis Manual. Available online: https://www.andeal.org/vault/2440/web/files/2016_April_EA_Manual.pdf (accessed on 18 September 2018).
43. Devlin, B.L.; Leveritt, M.D.; Kingsley, M.; Belski, R. Dietary Intake, Body Composition, and Nutrition Knowledge of Australian Football and Soccer Players: Implications for Sports Nutrition Professionals in Practice. *Int. J. Sport Nutr. Exerc. Metab.* **2017**, *27*, 130–138. [CrossRef]
44. Maughan, R.J.; Burke, L.M. Practical Nutritional Recommendations for the Athlete. *Nestle Nutr. Inst. Workshop Ser.* **2011**, *69*, 131–149. [CrossRef]
45. Lemon, P.W. Protein requirements of soccer. *J. Sports Sci.* **1994**, *12*, S17–S22. [CrossRef] [PubMed]
46. Hernandez, A.J.; Nahas, R.M. Modificações dietéticas, reposição hídrica, suplementos alimentares e drogas: comprovação de ação ergogênica e potenciais riscos para a saúde. *Rev. Bras. Med. Esporte* **2009**, *15*, 1–12.
47. Mettler, S.; Mitchell, N.; Tipton, K.D. Increased Protein Intake Reduces Lean Body Mass Loss during Weight Loss in Athletes. *Med. Sci. Sports Exerc.* **2010**, *42*, 326–337. [CrossRef] [PubMed]
48. Tipton, K.D.; Wolfe, R.R. Protein and amino acids for athletes. *J. Sports Sci.* **2004**, *22*, 65–79. [CrossRef]
49. Bishop, N.C.; Blannin, A.K.; Walsh, N.P.; Robson, P.J.; Gleeson, M. Nutritional Aspects of Immunosuppression in Athletes. *Sports Med.* **1999**, *28*, 151–176. [CrossRef] [PubMed]
50. American College of Sports Medicine author issuing body. *ACSM's Guidelines for Exercise Testing and Prescription*, 10th ed.; Wolters Kluwer Health: Philadelphia, PA, USA, 2018.
51. Phillips, S.M.; Van Loon, L.J. Dietary protein for athletes: From requirements to optimum adaptation. *J. Sports Sci.* **2011**, *29*, S29–S38. [CrossRef] [PubMed]
52. Nutrition for football: The FIFA/F-MARC Consensus Conference. *J. Sports Sci.* **2006**, *24*, 663–664. [CrossRef]
53. Bussau, V.A.; Fairchild, T.J.; Rao, A.; Steele, P.; Fournier, P.A. Carbohydrate loading in human muscle: An improved 1 day protocol. *Eur. J. Appli. Physiol.* **2002**, *87*, 290–295. [CrossRef]
54. Krustrup, P.; Mohr, M.; Steensberg, A.; Bencke, J.; Kjær, M.; Bangsbo, J. Muscle and Blood Metabolites during a Soccer Game: Implications for Sprint Performance. *Med. Sci. Sports Exerc.* **2006**, *38*, 1165–1174. [CrossRef]
55. Hargreaves, M. Carbohydrate and lipid requirements of soccer. *J. Sports Sci.* **1994**, *12*, S13–S16. [CrossRef] [PubMed]
56. Bradley, W.J.; Hannon, M.P.; Benford, V.; Morehen, J.C.; Twist, C.; Shepherd, S.; Cocks, M.; Impey, S.G.; Cooper, R.G.; Morton, J.P.; et al. Metabolic demands and replenishment of muscle glycogen after a rugby league match simulation protocol. *J. Sci. Med. Sport* **2017**, *20*, 878–883. [CrossRef] [PubMed]

57. Burke, L.M.; Loucks, A.B.; Broad, N. Energy and carbohydrate for training and recovery. *J. Sports Sci.* **2006**, *24*, 675–685. [CrossRef] [PubMed]
58. Collins, J.; McCall, A.; Bilsborough, J.; Maughan, R. Football nutrition: time for a new consensus? *Br. J. Sports Med.* **2017**, *51*, 1577–1578. [CrossRef] [PubMed]
59. Impey, S.G.; Hammond, K.M.; Shepherd, S.O.; Sharples, A.P.; Stewart, C.; Limb, M.; Smith, K.; Philp, A.; Jeromson, S.; Hamilton, D.L.; et al. Fuel for the work required: A practical approach to amalgamating train-low paradigms for endurance athletes. *Physiol. Rep.* **2016**, *4*, e12803. [CrossRef] [PubMed]
60. Areta, J.L.; Burke, L.M.; Camera, D.M.; West, D.W.; Crawshay, S.; Moore, D.R.; Stellingwerff, T.; Phillips, S.M.; Hawley, J.A.; Coffey, V.G. Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. *Am. J. Physiol. Endocrinol. Metab.* **2014**, *306*, E989–E997. [CrossRef]
61. National Health and Medical Research Council. *Australian Guide to Healthy Eating*; NHMRC: Canberra, Australia, 2013.
62. Lundy, B.; O'Connor, H.; Pelly, F.; Caterson, I. Anthropometric characteristics and competition dietary intakes of professional rugby league players. *Int. J. Sport Nutr. Exerc. Metab.* **2006**, *16*, 199–213. [CrossRef]

CHAPTER FOUR

4.1. Preface

Citation (4.2.): **Jenner S.L**., Trakman G., Coutts A., Kempton T., Ryan S., Forsyth A., Belski, R. Dietary intake of professional Australian Football athletes surrounding body composition assessment. Journal of the International Society of Sports Nutrition. 2018;15(1).

Chapter three identified that professional and semi-professional team sport athletes do not consume diets that meet sports nutrition recommendations for energy and CHO. In addition, Chapter one identified that prior to this PhD research, AF athletes had limited access to nutrition from a sports nutrition professional. It was hypothesised that AF athletes at the AF club would also consume diets that do not align with sports nutrition recommendations and would have poor NK. Furthermore, from anecdotal reports it was hypothesised that AF athletes reduce CHO intake prior to a body composition assessment (i.e. DXA scan). Therefore, research included in Chapter four aimed to assess the DIs and NK of professional male AF athletes to identify gaps requiring nutrition intervention and to provide insight for sports nutrition professionals.

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RESEARCH ARTICLE Open Access

Dietary intake of professional Australian football athletes surrounding body composition assessment

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Abstract

Background: Sports Dietitians aim to assist in improving performance by developing nutrition knowledge (NK), enhancing dietary intake and optimising body composition of athletes. In a high-pressure environment, it is important to identify factors that may compromise an athlete's nutrition status. Body composition assessments are regularly undertaken in sport to provide feedback on training adaptions; however, no research has explored the impact of these assessments on the dietary intake of professional athletes.

Methods: This cross-sectional study assessed dietary intake (7-day food diary), nutrition knowledge (Nutrition for Sport Knowledge Questionnaire) and body composition (Dual-energy X-ray absorptiometry) of 46 professional male Australian football (AFL) athletes during a 2017 pre-season training week (7 days) where body composition assessments were undertaken. Dietary intake was assessed against International Olympic Committee recommendations for professional athletes.

Results: Overall, no athlete met dietary their recommended energy intake (15 ± 1.1 vs. 9.1 ± 1.8 MJ, respectively) or carbohydrate recommendations (6–10 vs. 2.4 ± 0.9 g·kg-1·day-1). Only 54% met protein recommendations. Secondary analyses demonstrated significant associations between education status and energy intake ($P < 0.04$) and vegetable intake ($P < 0.03$), with higher levels of education being associated with higher intakes. A moderately positive association was observed between NK scores and meeting estimated energy requirements ($r = 0.33$, $P = 0.03$). NK scores were also positively associated with protein ($r = 0.35$, $P = 0.02$), fibre ($r = 0.51$, $P = 0.001$) and calcium intakes ($r = 0.43$, $P = 0.004$).

Conclusions: This research identified that the dietary intake of professional AFL athletes during a pre-season training week where body composition assessments were undertaken did not meet current recommendations. Several factors may influence the dietary intake of AFL athletes, including lower education levels, poor NK and dietary intake restriction surrounding body composition assessment. Athletes may require support to continue with performance-based nutrition plans in periods surrounding body composition assessment.

Keywords: Sports nutrition, Nutrition knowledge, Diet quality, Team-based sport

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Background

Australian football (AF) is an intermittent high intensity team sport with intense periods of play, interspersed with periods of recovery [1]. At the professional level, Australian football (AFL) athletes train over a season that is divided into pre-season (~ 4 months) and competition (~ 6 months) phases. Training demands are substantial with athletes covering up to 30 km of total distance during a typical pre-season week, with a modified training volume performed in-season with the addition of match-play [2]. Moreover, athletes complete other training modalities (i.e. weights, cross training) to complement these running volumes in preparation for match demands. For a professional AFL athlete to meet training and performance demands and achieve body composition goals, energy and macronutrient intakes must reflect training and competition loads [3]. Therefore, dietitians have increasingly become recognized as an integral part of high performance teams. Their role is to promote optimal nutrition and to support, direct and teach sustainable nutrition practices to athletes in accordance with their training loads and body composition goals. Advice provided by accredited dietitians is guided by evidence-based recommendations that focus on periodization of energy, macronutrient and fluid intake, according to individual characteristics and body composition goals [4, 5].

Due to the high intensity nature of AF training and match play; adequate energy intake is required to maintain lean muscle mass, refuel energy stores and promote optimal performance [6]. However, research has reported that athletes across a range of team sports consistently fail to meet energy and carbohydrate recommendations [3, 6, 7]. The difficulties athletes experience when trying to consume a well-balanced diet and meet energy recommendations have also been reported [8, 9]. Many individual and environmental factors including knowledge and skills, peers and team culture, time constraints, finances and access to healthy food have been found to influence the dietary intake of athletes [6, 8, 10–12].

Nutrition knowledge (NK) is also thought to influence the dietary intake of individuals [11]. General knowledge behaviour models suggest that if an individual is aware of the benefits of nutrition they are more likely to make informed decisions regarding their health [13]. The link between NK and dietary behaviours has been examined in previous research, with weak to moderate positive associations reported in a variety of athletes [6, 7, 11]. While this research has underlined the importance of athlete NK and subsequent behaviour, most studies have only observed small samples of team sport athletes and used NK assessments that do not correspond with current IOC intake recommendations [14].

Coaches and high performance staff often assign athletes body composition goals such as reducing body fat and increasing lean muscle mass to develop a physique that can tolerate training loads and match demands [3]. Although body composition goals are present in professional sport, no research has established the impact of these goals on adequate intake. These goals are likely to influence the dietary intake of athletes, particularly during times of body composition assessment. However, in efforts to achieve body composition goals, restriction of dietary intake may occur and in times of high training loads may impair recovery, increase the likelihood of injury or illness and decrease overall performance (i.e. symptoms of overtraining) [8, 15, 16]. Body composition measurements may be collected during different training phases, so it is important to explore the extent to which body composition goals influence dietary intake, to inform strategies to support athletes to maintain adequate dietary intake required for performance.

Our primary aim was to examine the energy and macronutrient intakes of AFL athletes during a pre-season training week where body composition assessments were undertaken. Secondary aims included assessing intake of other nutrients and athletes' NK as well as relationships between intake and factors including: age, playing experience and education status. We hypothesised that athletes were likely to have inadequate dietary intakes surrounding body composition assessment.

Methods

Participants

Athletes were recruited from one club competing in the AFL by the sports dietitian. Athlete characteristics (i.e. age and playing experience) and body composition data are reported in Table 1. Body composition (i.e. body fat percentage (%BF), fat free mass (FFM), height and body mass) was assessed using gold standard measure Dual-energy X-ray absorptiometry (DXA), following a method previously described elsewhere [3, 17].

Dietary intake

Dietary intake was assessed using 7-day estimated food diaries collected during the pre-season phase of the season where body composition assessment was taking

Table 1 Participant characteristics

Characteristics	Mean ± SD
Age (years)	24.2 ± 4.0
Professional Experience (years)	5.5 ± 3.1
Height (cm)	188.4 ± 8.5
Body mass (kg)	86.3 ± 9.4
Body fat (%)	10.8 ± 2.3
Fat free mass (kg)	73.9 ± 9.1

place. A 7-day food diary was selected as this time period captures a typical training micro-cycle in this athlete cohort, which includes three main skills sessions and all other training modalities [2]. Specifically, the observation period included three main training days (containing one skills training session [60–70 min] and one weights session [50 min] per day), one light training day (one short skills training session [40 min], one short weights session [30 min] per day) and three recovery days (no scheduled activity). Data was collected using the 'Easy Diet Diary' App ($n = 41$), 'WhatsApp' ($n = 4$) and one written food diary. The 'Easy Diet Diary' App was selected as it uses a database of Australian foods, has been validated as a method of assessing dietary intake in groups and provides a more convenient way of recording dietary intake than conventional written methods [18, 19]. The application 'WhatsApp' was used for four participants who could not access 'Easy Diet Diary' due to logistical issues. Food diaries estimated intake of all foods, fluids and supplements consumed on these days. Dietary intake data was analysed using a nutrition composition software program (Foodworks Version 8, Xyris, Queensland). Average daily energy and macronutrient intakes were analysed against current American College of Sports Medicine (ACSM) and International Olympic Committee (IOC) recommendations [4, 20, 21]. Individual energy requirements were estimated using the Harris-Benedict equation, using activity factors that reflected training loads [22]. Activity factors were categorised according to main, light and recovery training days (i.e. main: 1.75, light: 1.55 and recovery: 1.375). Intake was assessed in terms of food groups, calcium and fibre content relative to current Australian Guide to Healthy Eating (AGHE) and Nutrient Reference Values (NRVs) respectively [23, 24]. Under-reporting of energy intake was assessed using Goldberg thresholds [25]. A ratio of reported energy intake (EI) and basal metabolic rate (BMR) was calculated and compared to the cut-off limits of 0.9. Under-reporters were additionally evaluated against body composition goals.

Nutrition knowledge

NK was assessed using the previously validated Nutrition for Sport Knowledge Questionnaire (NSKQ) [26]. The demographic section of the NSKQ asks about athlete characteristics (i.e. age and playing experience). The NSKQ contains 89 knowledge questions that assess various principles of sports nutrition. It is divided into six NK sub-sections; Weight Management ($n = 13$), Macronutrients ($n = 30$), Micronutrients ($n = 13$), Sports Nutrition principles ($n = 13$), Supplements ($n = 12$) and Alcohol ($n = 8$). Knowledge scores were calculated according to the NSKQ protocol [26]. Athletes were instructed to select agree/disagree or choose the correct answer from 4 to 5 possible options; they were told to select 'not sure' when appropriate. Overall performance in the NSKQ was assessed using the scoring system of; "poor" knowledge (0–49%), "average" knowledge (50–65%), "good" knowledge (66–75%) and "excellent" knowledge (75–100%) [26]. Participants were asked to complete the questionnaire using their own knowledge without the use of other resources (i.e. internet, peers etc.). All questionnaires were completed within a specified period of 7 days, consistent among individuals, in conjunction with the collection of dietary intake (i.e. 7-day food diary) and body composition data. Responses to an additional 19 investigator-designed questions regarding the participants' views on current dietetic support, preferred means of education, self-efficacy of cooking skills and nutrition habits (i.e. portion sizes and periodization) were also collected. Responses to these additional questions were not included as a part of the overall knowledge score.

Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics for Windows Version 24.0 (IBM Corp, Armonk, New York, USA, 2013). Statistical significance was set at $p < 0.05$. Shapiro-Wilk test for normality was used to assess if the data was normally distributed. Data was presented as means, standard deviations (±) and percentage of energy and macronutrient requirements (%) met, unless otherwise specified. Independent and paired sample t tests and ANOVA were used to assess significance between different groups (i.e. age, playing experience, education status). The proportion of participants meeting dietary intake recommendations for energy, carbohydrate, protein, fat, fibre, calcium and food groups (i.e. fruit and vegetable) was reported (Table 2). Dietary intake was then analysed in tertiles (i.e. low, medium, high intakes) against NK, age (years), playing experience (years) and education status, using a Chi-square test for independence.

Pearson's correlation coefficient was used to describe the correlation between NK (i.e. overall score and subsection scores) and diet quality (i.e. % met total energy, macronutrients, fibre, calcium and food groups). They were interpreted according to correlation size (small: $r = 0.10–0.29$, moderate: $r = 0.30–0.49$ and large: $r = 0.50–1.0$) [27, 28].

Results

Dietary intake and body composition

None of the participants met current recommendations for energy and carbohydrate intake and only 54% met protein recommendations (Table 2). The majority also failed to meet calcium and fibre recommendations (Table 2). The majority (78%) of participants' EI:BMR ratios were calculated as being below the Goldberg cut-off

Table 2 Total Energy, Macronutrient, Micronutrient (Calcium) and Food group intakes (mean ± SD) collected via a 7-day food diary

	Recommended Intake	Average per day (mean ± SD)	Number of Participants meeting recommendations (%, n)
Energy (MJ)	~ 15 MJ	9.1 ± 1.8	0 (n = 0)
Carbohydrate ($g \cdot kg^{-1} \cdot day^{-1}$)	6–10 $g \cdot kg^{-1} \cdot day^{-1}$	2.4 ± 0.8	0 (n = 0)
Protein ($g \cdot kg^{-1} \cdot day^{-1}$)	1.2–2.0 $g \cdot kg^{-1} \cdot day^{-1}$	1.8 ± 0.4	54 (n = 25)
Fat ($g \cdot kg^{-1} \cdot day^{-1}$)	20–35% total energy	0.9 ± 0.3	91 (n = 42)
Fruit (serves)	2 serves per day	1.0 ± 0.8	91 (n = 42)
Vegetable (serves)	5 serves per day	4.3 ± 1.7	70 (n = 32)
Calcium (mg)	1000 $mg\text{-}day^{-1}$	952 ± 287	44 (n = 20)
Fibre (g)	30 $g\text{-}day^{-1}$	27.0 ± 7.6	37 (n = 17)

Energy and fat recommended intake as per American College of Sports Medicine (ACSM) [4]
Carbohydrate and protein recommended intake as per International Olympic Committee (IOC) [18]
Calcium and Fibre recommended as per Australian Nutrient Reference Values [21]
Fruit and Vegetable recommended intake as per AGHE recommendations [22]

limit of 0.9 for a plausible intake. Participants who were not classified as under-reporters had body composition goals that aimed to increase total mass. Periodization of macronutrients such as carbohydrate was found to be inconsistent with recommendations, with food diaries demonstrating that the highest carbohydrate intake was found on light training days, followed by main training and recovery days respectively. On main training days, refined carbohydrate sources (i.e. processed and high GI carbohydrate foods) made up 60% ± 20% of total carbohydrate intake.

Dietary intake and other factors

Relationships between meeting and not meeting recommendations for intake of total energy, carbohydrate, protein, fat, fibre, calcium and food groups (i.e. fruit and vegetable) and education status, level of playing experience and age were explored. Significant positive associations were found between education status and energy intake ($P = 0.037$) and vegetable intake ($P = 0.028$). There were no significant relationships found between education status and carbohydrate, protein, fat, fibre, calcium and fruit intake. No significant relationships were found between measures of dietary intake and age or level of playing experience.

Nutrition knowledge

The response rate for NSKQ was 100%. The mean NK score for participants was 41 ± 13 out of a possible 89 points (46% mean score). The data was normally distributed. While overall NK was poor, participants performed best in macronutrient, weight management and sports nutrition sections (Table 3). A detailed description of professional and recreational AF players' NK, assessed using the NSKQ are reported elsewhere [29].

Participants reported a high level of confidence in performing food related behaviours such as cooking a healthy meal (86.0 ± 1.2%). All participants responded that they sought nutrition advice and information from a dietitian (100%, $n = 46$) followed by teammates (80%, $n = 37$) and coach or trainer (41%, $n = 19$). There was a moderate positive association between NK scores and meeting estimated energy requirements ($r = 0.325$, $P = 0.031$). NK scores were also positively associated with protein ($r = 0.348$, $P = 0.021$), fibre ($r = 0.510$, $P = 0.001$) and calcium intakes ($r = 0.428$, $P = 0.004$).

Discussion

General findings

The aim of this study was to assess the dietary intake of professional AFL athletes during a pre-season training week where body composition assessments were undertaken.

Table 3 Participant's Nutrition for Sport Knowledge Questionnaire overall and subsection scores

Section/Subsection (total items)	Min	Max	Median	Mean ± SD	Mean % Accuracy	Performance in the NSKQ
Weight Management (13)	1	13	6	6.4 ± 2.4	49	Poor
Macronutrients (30)	4	29	17	17.2 ± 5.1	58	Average
Micronutrients (13)	0	10	6	5.1 ± 2.5	39	Poor
Sports Nutrition (13)	1	11	6	6.1 ± 2.9	47	Poor
Supplements (12)	0	8	3	3.3 ± 1.9	28	Poor
Alcohol (8)	0	7	5	4.2 ± 1.8	53	Average
Overall Total Score (89)	9	70	42	41 ± 13	46	Poor

NSKQ scoring; Poor (0–49%), Average (50–65%), Above average (66–75%), Excellent (75–100%) [24]

The main findings of the current study were (1) none of the AFL athletes met recommendations for energy or carbohydrate, (2) there was a moderate, positive association between NK and meeting energy requirements, (3) on average athletes had poor nutrition knowledge and (4) higher levels of education were associated with higher intakes of energy and vegetables. This supported our hypothesis that athletes would have inadequate dietary intakes surrounding body composition assessment.

Effects of body composition goals on dietary intake

When data was explored in tertiles (i.e. low, medium and high) of energy intake, we found that athletes who had a greater energy intake reported a higher education status. Research by Johansson et al. explored under and over reporting of dietary intake in a non-athlete population and found a positive relationship between energy intake and education status [30]. Collectively, this suggests that education status may positively influence energy intake. Nonetheless, while education status improved energy intake in this cohort, 100% of athletes failed to meet energy intake recommendations [4, 20, 21]. Future research may explore the efficacy of different energy intake education approaches and other factors pertaining to energy intake in these athletes. However, although 78% of participants' EI:BMR were calculated as being below the Goldberg cut-off of limit of 0.9 for a plausible intake, it is recognised that a lower than expected EI:BMR value may not simply be "under-reporting" but may instead indicate dieting or unusually low consumption during this training week. In this study, reports from participants suggest that whilst they did not meet energy and macronutrient recommendations, the food diaries are likely to be representative of actual dietary intake during that time period and low intakes are not due to under-reporting. Athletes are faced with external influences that may challenge diet adequacy and recovery. Body composition goals and pressures for athletes to make weight are a widely researched topic in professional sport [31, 32]. In particular, research has suggested that when body composition goals are present (i.e. required to lose fat mass or maintain a lean physique) there is usually an energy deficit and macronutrients required for refuelling and recovery are reduced [15]. In this study, food diaries were recorded during a time when the body composition of the AFL athletes was being assessed via DEXA scan. It is possible there was an intentional restriction of energy and carbohydrate intake as a result of aiming to meet the target body composition goals set for athletes, which was reflected in food records. This is supported by research that reported a desire for weight reduction as an explanation for failing to meet energy intake guidelines [30]. Taken together, our findings and those of others may indicate that psychological factors not quantified in this study may contribute to energy intake. To prevent training adaptions and recovery being compromised, it is important to promote realistic body composition goals to athletes. Future studies may use qualitative methods to explore the reasons for athletes not meeting energy and macronutrient recommendations in the time prior to a body composition assessment, and to highlight periods where under-fuelling may be present. This information may also provide a greater insight into the scheduling of body composition assessments in professional AFL programs. To promote a diet that supports performance and decrease the risk of injury, DXA scans may need to be avoided around key training sessions and game days.

Other factors affecting energy and carbohydrate intake

Fluctuations in dietary intake that occur over a training week can be a result of several factors including hormonal influences on appetite regulation and time constraints within training schedules. Self-reported energy intake showed a level of periodization, with the largest energy intake reported on main training days followed by light and recovery days respectively. Similarly, participants had a good level of understanding of sport nutrition principles regarding periodization of carbohydrates and energy availability. Indeed, most participants (59%) reported that 'periodizing energy and carbohydrate intake (i.e. high versus low days)' was good practice for body composition management and performance [33]. Despite good knowledge of energy and carbohydrate periodization principles, total intake did not meet recommendations. Maintaining a diet that is energy and macronutrient deficient can increase the risk of illness and injury, promote weight loss (including losses to lean muscle mass) and alter performance outcomes [4]. Reasons why athletes may not consume adequate nutrients and energy during weeks of high training loads have previously been explored [8, 9]. In particular, physiological factors such as hormones may affect an athlete's ability to consume the right amount of nutrients and energy required on main training days. Research has explored the influence of high intensity training on changes to appetite hormones and found that hormones such as ghrelin, glucagon-like peptide-1 (GLP-1), pancreatic polypeptide (PP) and peptide YY (PYY) may contribute to suppressed hunger post physical activity [9]. Furthermore, logistical issues such as time constraints on main training days may have additionally limited participants' ability to consume adequate nutrition on main training days. Indeed, athletes appeared to choose convenient, energy dense snacks and refined carbohydrate sources on main training days. The potential provision of meals in this professional setting may positively support dietary intake over a training week. Future research may investigate whether the provision of meals in professional settings with the inclusion of flexible meal times in training schedules to accommodate those that experience supressed appetite post training can have a positive influence on athletes' dietary intake over a training week.

Carbohydrate intake

This study demonstrated that on average, AFL athletes' dietary carbohydrate intake was relatively low in comparison to requirements based on training loads [3, 6]. This corresponds with previous research that reported dietary intakes of Australian footballers to fall below carbohydrate recommendations [3, 6]. Mean dietary carbohydrate intakes (2.4 ± 0.7 g·kg^{-1}·day^{-1}) fell below the lower range of sports nutrition guidelines advocated by the IOC (3–12 g·kg^{-1}·day^{-1}) [4, 34]. Carbohydrate is a key fuel used for high-intensity aerobic based sports like Australian football and plays a vital role as a muscle substrate for performance and recovery [35]. Low carbohydrate availability can lead to muscle glycogen depletion and subsequent fatigue, impaired concentration and decreased physical output [34, 36].

Research has suggested that carbohydrate intake is often the main macronutrient restricted by individuals to meet body composition goals [15]. Athletes had overall sound knowledge in the NSKQ macronutrients subsection, however it was found that knowledge regarding carbohydrate recommendations was poor. Therefore, poor NK may contribute to athletes having under-consumed carbohydrate. A large proportion of participants (41%) were 'Not Sure' regarding carbohydrate recommendations for athletes undertaking moderate to high intensity physical activity and only 24% of participants correctly identified carbohydrate recommendations. The present results are consistent with previous research, which found that 53% of collegiate athletes, when asked to identify carbohydrate recommendations, selected values that fell below carbohydrate recommendations advocated by sports nutrition experts [37, 38]. Previous findings show athletes have a misconception regarding carbohydrate availability (i.e. carbohydrate intake is related to body fat gains) and taken together the results of this study suggests that there is a knowledge gap regarding the importance of carbohydrate as a main fuel. It is important to promote individualised carbohydrate recommendations according to training requirements to support body composition goals and training adaptions of athletes. Further education that highlights the important role of carbohydrate in fuelling training and competition may be required, in addition to tailored advice to improve carbohydrate intake.

Protein intake

Self-reported protein intakes in the present study were equal to or in excess of current recommendations for football and power sports [39]. Current recommendations suggest an absolute dose of 20–40 g per serve [39]. Indeed, 30% correctly responded to the statement '*Protein absorption in a single sitting is limited*'. Despite this, only 15% of participants reported that their usual serving size aligned with this recommended serve. It has been suggested that when energy availability is low (due to energy restriction aiming for weight loss), protein intake may be increased, to preserve muscle mass [40]. Due to the overall low energy intakes reported by athletes, excess protein ingestion may have been required to meet training demands. Extensive media attention regarding high protein, low carbohydrate diets may have additionally negatively influenced knowledge–creating an uncertainty regarding the distribution of macronutrients in the diet [10]. Future research could examine the scope of effect that media messages promoting low carbohydrate, high protein diets for weight loss, has on individuals' dietary behaviours. Likewise, providing information regarding an athlete's individual protein requirement and linking this information with education tools that focus on portion sizes of protein (e.g. serving size plates, visual portion guides) may help guide informed decisions about protein and simultaneously promote carbohydrate intakes that are better aligned with current guidelines.

Nutrition education and dietetic support

Athletes were asked to give feedback regarding current dietetic support. Participants ranked individual consults as the most useful means of obtaining nutrition advice, in contrast to group presentations that were ranked as least useful. Given the findings of this study and the suitability of practical group based education in professional sport, these programs may need to include a more individualised approach that includes a greater focus on providing evidence-based information regarding energy and macronutrient requirements. Education that links dietary intake to performance may act as a motivator for behaviour change and limit the impact of other external factors, such as body composition assessments, on intake. Future research may investigate the efficacy of current practical nutrition education strategies such as cooking programs, in order to determine their effectiveness with the professional athlete cohort.

Limitations

While this study aimed to assess the dietary intake of professional AFL athletes, it possesses several limitations. Firstly, the study sample included only one professional AFL team ($n = 46$) therefore the findings may reflect the individual characteristics and demographics of the group observed. Moreover, time constraints meant that only cross-sectional data could be collected. In addition to this, weighed food diaries are considered gold standard when assessing dietary intake in athletes; however, due to time and logistical constraints estimated food diaries were deemed the most appropriate method for use in this study.

Under-reporting is a well-documented limitation when using diet-recall methodologies to report nutrient intakes, especially in healthy cohorts [41]. Due to technological issues, 4 of the 46 participants in this study used 'WhatsApp' to report their dietary intake, as opposed to the vast majority of participants ($n = 41$) who used 'Easy Diet Diary'. Those participants using 'WhatsApp' sent photos of their meals to the dietitian, who estimated portions and nutrient intake from this information, possibly resulting in the inaccurate measurement of dietary intake.

Conclusion

This research provides insight into the dietary intake of AFL athletes during a pre-season training week where body composition assessments were undertaken. Our findings demonstrated that overall dietary intake did not meet recommendations. None of the athletes who participated in the study met energy or carbohydrate recommendations and only half met protein recommendations. Higher levels of education were associated with higher intakes of energy and vegetables and NK scores were also positively associated with meeting estimated energy requirements and protein, fibre and calcium intakes, demonstrating that several factors may influence the dietary intake of AFL athletes, including lower education levels, poor NK and dietary intake restriction surrounding body composition assessment. Athletes may require support to continue with performance-based nutrition plans in periods surrounding body composition assessment. We recommend the inclusion of individually tailored education programs to highlight the importance of dietary intake on body composition and performance, in addition to practical strategies to achieve recommended dietary intake.

Abbreviations

AF: Australian Football; AFL: Australian Football League; DXA: Dual energy X-ray absorptiometry; NK: Nutrition Knowledge; NSKQ: Nutrition for Sport Knowledge Questionnaire

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Availability of data and materials

All datasets generated during this study are included in this published article.

Authors' contributions

The study was designed by SJ and RB. SJ collected and analysed the data. TK, AC, RB, AF assisted with the data interpretation. All authors assisted with manuscript revision and approved the final manuscript.

Ethics approval and consent to participate

The La Trobe University Human Research Ethics Committee approved the study (S17–025). All participants were informed about the procedures and signed an informed consent form prior to commencement of the research.

Consent for publication

Participants signed consent forms for publication.

Competing interests

The authors declare that they have no competing interests.

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References

1. Coutts AJ, Quinn J, Hocking J, Castagna C, Rampinini E. Match running performance in elite Australian rules football. J Sci Med Sport. 2009;13(5):543–8.
2. Ritchie D, Hopkins WG, Buchheit M, Cordy J, Bartlett JD. Quantification of training and competition load across a season in an elite Australian football Club. Int J Sports Physiol Perform. 2016;11(4):474.
3. Bilsborough JC, Greenway K, Livingston S, Cordy J, Coutts A. Changes in anthropometry, upper-body strength and nutrient intake in professional Australian football players during a season. Int J Sports Physiol Perform. 2016;11:290–300.
4. Potgieter S. Sport nutrition: a review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the International Society for Sports Nutrition. S Afr J Clin Nutr. 2013;26(1):6–16.
5. Burke L. Practical issues in nutrition for athletes. J Sports Sci. 1995;13(1):83–90.
6. Devlin BL, Leveritt MD, Kingsley M, Belski R. Dietary intake, body composition, and nutrition knowledge of Australian football and soccer players: implications for sports nutrition professionals in practice. Int J Sports Nutr Exerc Metab. 2016;27(2):130–8.
7. Spronk I, Heaney SE, Prvan T, O'Connor HT. Relationship between general nutrition knowledge and dietary quality in elite athletes. Int J Sports Nutr Exerc Metab. 2015;25(3):243–51.
8. Kreider RB, Wilborn CD, Taylor L, Campbell B, Almada AL, Collins R, et al. ISSN exercise & sport nutrition review: research & recommendations. J Int Soc Sports Nutr. 2010;7:7.
9. Schubert M, Sabapathy S, Leveritt M, Desbrow B. Acute exercise and hormones related to appetite regulation: a meta-analysis. Sports Med. 2014;44(3):387–403.
10. Spendlove J, Heaney S, Gifford JA, Prvan T, Denyer GS, O'Connor H. Evaluation of general nutrition knowledge in elite Australian athletes. Br J Nutr. 2012;107(12):1871–80.
11. Heaney S, O'Connor H, Michael S, Gifford J, Naughton G. Nutrition knowledge in athletes: a systematic review. Int J Sports Nutr Exerc Metab. 2011;21:248–61.
12. Wardle J, Parmenter K, Waller J. Nutrition knowledge and food intake. Appetite. 2000;34:269–75.
13. Worsley A. Nutrition knowledge and food consumption: can nutrition knowledge change food behaviour? Asia Pac J Clin Nutr. 2002;11(3):579–85.
14. Trakman GL, Forsyth A, Devlin BL, Belski R. A systematic review of athletes' and coaches' nutrition knowledge and reflections on the quality of current nutrition knowledge measures. Nutrients. 2016;8.
15. Burke L, Cox G, Cummings N, Desbrow B. Guidelines for daily carbohydrate intake - Do athletes achieve them? Sports Med. 2001;31:267.
16. Turocy PS, DePalma BF, Horswill CA, Laquale KM, Martin TJ, Perry AC, et al. National Athletic Trainers' association position statement: safe weight loss and maintenance practices in sport and exercise. J Athlet Train. 2011;46(3):322–36.

17. Santos DA, Gobbo LA, Matias CN, Petroski EL, Gonçalves EM, Cyrino ES, et al. Body composition in taller individuals using DXA: a validation study for athletic and non-athletic populations. J Sports Sci. 2013;31(4):405–13.
18. Rangan AM, O'Connor S, Giannelli V, Yap MLH, Tang LM, Roy R, et al. Electronic dietary intake assessment (e-DIA): comparison of a Mobile phone digital entry app for dietary data collection with 24-hour dietary recalls. JMIR MHealth UHealth. 2015;3(4):e98.
19. Shim J-S, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiol Health. 2014;36:e2014009.
20. International Olympic Committee. IOC consensus statement on sports nutrition 2010. J Sports Sci. 2011;29:S3-S4.
21. Rodriguez NR, Dimarco NM, Langley S. Position of the American dietetic association, dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. J Am Diet Assoc. 2009;109(3):509.
22. Burke L, Deakin V. Clinical sports nutrition. Australia: Mcgraw Hill; 2015.
23. National Health and Medical Research Council. Nutrient reference values for Australia and New Zealand including recommended dietary intakes. Canberra: NHMRC; 2006.
24. National Health and Medical Research Council. Educator Guide. Canberra: NHMRC; 2013.
25. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr. 1991;45(12):569.
26. Trakman GL, Forsyth A, Hoye R, Belski R. The nutrition for sport knowledge questionnaire (NSKQ): development and validation using classical test theory and Rasch analysis. J Int Soc Sports Nutr. 2017;14:26.
27. Cohen J, Cohen P. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum Associates; 1988.
28. Hopkins GW, Marshall WS, Batterham MA, Hanin MJ. Progressive statistics for studies in sports medicine and exercise science. Med & Sci Sports & Exerc. 2009;41(1):3–12.
29. Trakman G, Forsyth A, Middleton K, Jenner S, Keenan S. R. B. Athletes lack awareness of consensus sports nutrition recommendations international journal of sports nutrition and exercise. 2018.
30. Johansson L, Solvoll K, Bjørneboe GE, Drevon CA. Under- and overreporting of energy intake related to weight status and lifestyle in a nationwide sample. Am J Clin Nutr. 1998;68(2):266–74.
31. Aragon AA, Schoenfeld B, Wildman R, Kleiner S, Vandusseldorp T, Taylor L, et al. International society of sports nutrition position stand: diets and body composition. J Int Soc Sports Nutr. 2017;14(1):16.
32. Heaney S, Connor H, Gifford J, Naughton G. Comparison of strategies for assessing nutritional adequacy in elite female athletes; dietary intake. Int J Sport Nutr Exerc Metab. 2010;20(3):245.
33. Close GL, Hamilton DL, Philp A, Burke LM, Morton JP. New strategies in sport nutrition to increase exercise performance. Free Radic Biol Med. 2016;98:144–58.
34. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Am Diet Assoc. 2000;100(12):1543-56.
35. Burke LM, Loucks AB, Broad N. Energy and carbohydrate for training and recovery. J Sports Sci. 2006;24(7):675–85.
36. Burke LM, Hawley JA, Wong SH, Jeukendrup AE. Carbohydrates for training and competition. J Sports Sci. 2011;29:17–27.
37. Weeden A, Olsen J, Batacan JM, Peterson T. Differences in collegiate athlete nutrition knowledge as determined by athlete characteristics. Sport J. 2014;12:1–13.
38. Alaunyte L, Perry JL, Aubrey T. Nutritional knowledge and eating habits of professional rugby league players: does knowledge translate into practice? J Int Soc Sports Nutr. 2015;12:18.
39. Jäger R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, et al. International Society of Sports Nutrition Position Stand: protein and exercise. J Int Soc Sports Nutr. 2017;14(20):1–25.
40. Areta J, Burke L, Camera D, West D, Crawshay S, Moore D, et al. Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. Am J Physiol Endocrinol Metab. 2014;306(8):E989–E97.
41. Scagliusi FB, Ferriolli E, Pfrimer K, Laureano C, Cunha CSF, Gualano B, et al. Under-reporting of energy intake is more prevalent in a healthy dietary pattern cluster. Br J Nutr. 2008;100(5):1060.

CHAPTER FIVE

5.1 Preface

Citation (5.2): **Jenner, S.L.**, Devlin, B., Forsyth, A., Belski, R. (2019). Dietary intakes of professional Australian Football League Women's (AFLW) athletes during a preseason training week. Journal of Science and Medicine in Sport. doi:10.1016/j.jsams.2019.06.014

Citation (5.3): **Jenner S.L,** Devlin B., Forsyth A., Belski R. (2020). Assessing the nutrition knowledge of professional female Australian Football (AFLW) athletes. *Journal of Science and Medicine in Football*. 2020:1-6. doi.org/10.1080/24733938.2020.1752929

Chapter four identified that male AF athletes' DIs did not align with sports nutrition recommendations specifically for energy and CHO. Furthermore, male AF athletes were found to have poor NK, with a variety of knowledge gaps in sports nutrition, weight management, micronutrients and supplements, identified. Together, with previous research undertaken in semi-professional female AF athletes, it was hypothesised that female AF athletes would consume DIs that do not align with recommendations for energy, CHO, iron and calcium and would have poor NK. Therefore, research included in Chapter 5, aimed to provide the first DI and NK assessment of professional female AF athletes. In addition, this research aimed to identify gaps requiring nutrition education to provide insight for sports nutrition professionals working within professional female sport environments.

5.2. Dietary Intakes of Professional Australian Football League Women's (AFLW) Athletes During a Preseason Training Week

Article has been published in the Journal of Science and Medicine in Sport and is available online.

Citation: **Jenner, S.L.**, Devlin, B., Forsyth, A., Belski, R. (2019). Dietary intakes of professional Australian Football League Women's (AFLW) athletes during a preseason training week. Journal of Science and Medicine in Sport. doi:10.1016/j.jsams.2019.06.014

5.3. Assessing the Nutrition knowledge of Professional Female Australian Football (AFLW) Athletes.

Article has been published in the Journal of Science and Medicine in Football and is available online.

Citation (5.3): **Jenner S.L,** Devlin B., Forsyth A., Belski R. (2020). Assessing the nutrition knowledge of professional female Australian Football (AFLW) athletes. *Journal of Science and Medicine in Football*. 2020:1-6. doi.org/10.1080/24733938.2020.1752929

CHAPTER SIX

6.1. Preface

Citation (6.2): **Jenner, S. L.**, Belski, R., Devlin, B., Coutts, A., Kempton, T., Forsyth, A. (2020). A qualitative investigation of factors influencing the dietary intakes of professional Australian Football players. Sports Medicine *(Currently under review- 01/07/20)*

Chapter 2, Section 2.3 identified that food choice is complex and is influenced by a range of individual factors. In addition, Chapter four identified that no male AF athlete met CHO recommendations, warranting further investigation into factors that influence male AF athletes meeting their nutrition goals. Research included in Chapter 4, hypothesised that male AF athletes manipulate their food choice specifically reducing CHO-based foods prior to a body composition assessment (i.e. DXA scan) as a result of pressures associated with meeting body composition goals. Therefore, to explore this phenomenon further research included in this chapter, aimed to qualitatively explore the factors that influence professional male AF athletes' food choice and dietary behaviours and additionally investigate dietary patterns undertaken prior to a DXA scan. A combination of inductive and deductive approaches were used to develop questions included in the semi-structured interviews. Open ended questions were employed to explore male AF athletes' dietary behaviours and to identify factors influencing food choice.

6.2. A Qualitative Investigation of Factors Influencing the Dietary Intakes of Professional Australian Football Players

Abstract

Many professional AF players do not meet recommended sports nutrition guidelines despite having access to nutrition advice. There are a range of factors that can influence players' ability to meet their nutrition goals and awareness of the barriers players face is essential to ensure dietary advice translates into practice. Therefore, this qualitative research study aimed to explore the factors influencing AF players' DIs and food choice. Semi-structured interviews were conducted with twelve professional male AF players, aged 23.0 ± 4.3 years with 5.5 ± 4.1 years' experience in AF. Less experienced players restricted their CHO intake to meet body composition goals, particularly during preseason and surrounding body composition assessment. During the competition season players had a greater focus on performance and placed more emphasis on CHO intake in the lead up to matches. Players felt nutrition goals were easier to achieve when dietary choices were supported by their families and peers. One-on-one consults, provided by a sports nutrition professional (i.e. sports dietitian) were players' preferred mode of nutrition intervention. Individualised nutrition advice and education is required for less experienced AF players who may be more vulnerable to unsustainable dietary habits. Experienced AF players can support junior teammates by promoting positive team culture related to body composition, nutrition and performance.

Keywords: CHO; Body composition; Australian Football; Interviews; Education.

Abbreviations: Australian Football (AF), Nutrition knowledge (NK), Australian Football League (AFL), Dual-energy X-ray Absorptiometry (DXA), Fat free soft tissue mass (FFSTM), Fat mass (FM).

6.2.1. Introduction

Personal food choices are complex and influenced by the interaction between an individual's sense of self and their daily food activities (1). A variety of factors such as knowledge, attitude and sociodemographic characteristics challenge personal reflection and can influence an individuals' view on their eating practices (1). Eating in a social setting with families, friends and partners has also been linked to food choice. These social settings may influence how individuals perceive they are judged by others, influencing their food choice, body image and self-esteem (1, 2). Birkenhead and Slater (2015) highlighted a range of factors that can influence individual food choice for players including taste preferences, cultural and religious beliefs, access to food, price and convenience. Involvement in professional competition and awareness of nutrition for performance and recovery are thought to be further drivers of good nutrition (3). Additionally, potential concerns regarding body composition, stage of training and performance expectations have been suggested as more recent drivers of food choice within the athletic population, yet research on factors influencing food choice in the athletic population is largely unexplored (3).

For athletic performance, a well-designed diet that meets energy and macronutrient needs, as well as proper timing and distribution is essential (4-7). Despite the presence of specific nutrition recommendations within team sport environments, research over the past decade has found many players do not meet these recommendations for energy and/or CHO intake (8, 9). More recently, concerns have been raised regarding the influence of body composition goals on players' DI and perception of their nutrition goals (3, 4). Attempts to achieve optimal physique and meet body weight goals for performance can increase the presence of unrealistic weight loss practices, where in extreme cases elimination of one or more food groups or the consumption of restrictive dietary plans with low micronutrient density are evident (4). Pressure from peers or culture within a sport to meet performance goals can also contribute to unsustainable dietary practices (3).

AF is a unique sport that encompasses a range of physical demands including aerobic fitness, speed, power and agility (10). The AF season is divided into preseason (~4 months) and competition season (~6 months), which are performed over the southern hemisphere summer and winter months, respectively (10). AF players' nutritional intake will be determined by the training and competition undertaken. Earlier studies in AF have reported that AF players' DIs do not align with sports nutrition recommendations for CHO and that they have poor NK (8, 11). Access to nutrition education and advice is important to improve NK and support DIs to meet nutrition needs related to performance and recovery. Nutrition education with players has been shown to improve NK (12). To ensure intent translates into practice, understanding factors influencing players' food choice may help improve dietetic practice by allowing dietitians to individualise nutrition intervention and education programs to players' needs (3). Therefore, the present study aimed to qualitatively explore the factors influencing dietary habits and food choice of AF players.

6.2.2. Methods

6.2.2.1. Participants

AF players were approached and recruited face to face by the lead researcher (SJ), from one club competing professionally in the AFL. All players were selected using purposeful sampling to ensure the sample included players over the age of 18 years and with a variety of AFL experience levels (range: 2-12 years). At the time of data collection, athletes had access to one on one consultations with a sports dietitian, however due time constraints (i.e. employed part time) additional nutrition education was provided to athletes via group education which included cooking classes. In addition, in-house catering was not available, however athletes had access to external catering options (i.e. restaurants and in house café). To monitor body composition, Dual-energy X-ray Absorptiometry (DXA) scans were undertaken four times across the AFL season, with preparation guidelines provided to athletes that align with best practice protocols (i.e. athlete presentation, placement on scanning bed and technician precision) (13).

6.2.2.2. Design and sample

A qualitative approach was used to develop upon an existing theory regarding factors that influence AF player's ability to meet nutrition goals, as well as explore other possible factors. (14).

Therefore, a combination of inductive and deductive reasoning were used when developing interview questions. Questions were constructed using inquiry logic and designed to elicit responses that would provide a better understanding of the thought processes' behind food choice. Questions also aimed to identify any barriers players experience when trying to meet body composition goals (15). A deductive approach was used to develop interview questions related to DI surrounding assessment of body composition. An inductive approach was used to identify other factors that influence DI. Questions included in interviews were open-ended and allowed players to draw on their own nutrition goals and identify any drivers of food choice, with specific questions regarding players' dietary patterns prior to a body composition assessment (Table 19). Semi-structured interviews were deemed to be the most appropriate method to evoke players' perspectives as it allowed players the freedom to express their views on nutrition, body composition and nutrition intervention.

6.2.2.3. Procedure

Interviews took place during the competition season. To protect player privacy, the year data collection commenced is not reported here. Ethical approval was granted for all procedures used by the La Trobe University Human Research Ethics Committee. Interviews were conducted within the club's facilities and were audio-recorded with players' consent. Each interview ran for approximately 30 minutes and was facilitated by a researcher (SJ) who also served as the club dietitian. This was beneficial for data collection, given researcher (SJ) had established rapport with the recruited players and had an understanding of the demands and player experiences within the specific team sport environment. Interviews were composed of three main sections. Section one aimed to explore factors that influence (including those that support or hinder) DI and food choice. Based on the factors highlighted by Birkenhead and Slater (2015) players were probed to consider factors such as '*taste, access, team mates and training'* and whether these influenced their dietary behaviours (3). Section two explored players' preparation including dietary patterns in the weeks and days prior to a body composition assessment (DXA scan) period. Jenner et al. (2018) had

Table 19. Semi-structured interview questions.

Category explored	Question	Logic
Section one: Influences on food choice and dietary habits	What are the key things you think influence your food choices (Prompts: Taste, access, teammates, training)?	Establish internal and external factors that influence food choice and allows players to identify whether these factors are barriers to meeting nutrition goals
	Does your food intake vary over the season? - Is your food intake different in preseason versus in-season?	Establish whether players feel their dietary habits change depending on the season i.e. Pre and competition season
	Do training sessions (e.g. intensity, limited time) impact on your food choices or dietary habits?	Explores the impact of training on players' food choice and dietary habits.
	Can you think of any other factors that might influence your intake throughout the week?	Provides insight into other factors that influence dietary habits, that may not have been highlighted by research previously.
Section two: Current nutrition practices surrounding body composition assessment	Do you currently have any body composition goals? - Do you have BF percentage goals or lean muscle mass goals?	Establishes whether players have body composition goals and identifies whether goals are BF or lean muscle mass.
	In the **weeks** prior to a DXA scan – can you describe changes [if any] to your DI? - Is this different to a normal training week when DXA scans are not taking place?	Aims to identify if players change their DI in the weeks prior to a body composition assessment period and provides insight into the types of dietary habits that occur.
	In the **days** prior to a DXA scan – can you describe changes [if any] to your DI? - Is this different to a normal training week when DXA scans are not taking place? - Are there any foods you do or don't eat before a DXA scan?	Aims to identify if players change their DI in the days prior to a body composition assessment period and provides insight into the types of dietary habits that occur.
	Do you feel any pressures prior to a DXA scan? - Do you think these pressures [if any] influence your intake?	Explores players' feelings surrounding body composition assessment periods and perceptions about body composition and goals.
Section Three: Nutrition education and the role of the sports dietitian in team sport	Moving forward, is there any information regarding nutrition you are unsure about?	Provides a platform for players to provide feedback on nutrition intervention and education required to support DI meeting nutrition goals.
	What types of education would help you? (i.e. one on one consults, group education, cooking classes?)	Identifies types of education players prefer and provides an insight into preferred learning styles.

Abbreviations: BF; Body Fat, DXA: Dual Energy X-ray Absorptiometry, DI; Dietary Intake previously hypothesised that AF players adjusted DI including CHO intake prior to a DXA scan (15). Therefore, to explore this theory, section two included questions designed to provide insight into AF players' dietary patterns in the weeks and days surrounding body composition assessment periods. Researchers used a deductive style approach to explore the hypothesis generated by past research (15). Lastly, section three considered players' preferred method of nutrition education and types of nutrition services that were most helpful to guide food choice. This section allowed players to provide feedback regarding the utility of the sports dietitian and their own experiences with nutrition services. At the completion of interviews, players were asked to review transcript and confirm their response.

6.2.2.4. Analysis

All interviews were manually transcribed in full for coding by one researcher (SJ). Using methods described by Braun and Clarke (2006), a thematic analysis using both deductive and inductive approaches was undertaken by two members of the research team (SJ and AF) to identify key categories (16). This process allowed researchers to familiarise themselves with data, coding and identification of categories and themes. Transcripts were independently reviewed by two researchers (SJ and AF) and codes were assigned. Using a cross examination approach codes were used to identify emerging categories and sub-categories and through discussion themes were established (Table 20) (16). Codes were developed by authors to group themes and to identify supporting quotes (16).

6.2.3. Results

6.2.3.1. Participants

Thirteen AF players were approached to participate in the study, with twelve players providing consent to participate in semi-structured interviews. Mean age and AFL playing experience of players included was 23.0 ± 4.3 years and 5.5 ± 4.1 years, respectively.

6.2.3.2. Categories, Sub-categories and themes

Researchers developed four categories that helped to explore factors behind AF players' food choice and DI behaviours. Players highlighted a range of factors that influenced their food choice. Categories to describe factors that influence AF players' food choice include 1) body composition, 2) interpersonal factors (i.e. peers, family, access), 3) seasonal changes and 4) nutrition knowledge and support. The influence of body composition and interpersonal factors were highlighted as main categories to explain decisions behind food choice during an AFL season. Dietary strategies such as the manipulation of CHO intake and excessive fluid intake surrounding times where body composition assessments were being undertaken were reported by players. A thematic map (Figure 1) was created to demonstrate the influence of these four key categories on food choice (i.e. body composition, interpersonal factors, stage of competition season and nutrition knowledge and support) and their relationship with DI behaviours.

6.2.3.2.1. Category One: Body composition

6.2.3.2.2.1. Perceived pressures associated with body composition assessment and goals

Body composition goals were developed by sports professionals for each AF player. Players reported that a range of individuals were included in the decision-making behind body composition goals including strength and conditioning coach, dietitian, sports scientist, coach and/or themselves. Many players identified their own body composition goals, based on the physique of other players of the same body type or those competing in the same playing position.

Goals developed by the players themselves were often unrealistic and unnecessarily low in BF. Standards related to body composition were driven by team-mates and staff (previously outlined) and were perceived as a source of pressure by players.

"I don't think there's enough attention to how much muscle you've gained or lost'…there's a lot made out if you have put on a kilo of fat."

"And if you don't come back better than last time yeah there's a few pressures…"

"I don't think it's a healthy way to drive the performance [Body composition goals]"

“"And if you don’t come back better than last time yeah there’s a few pressures"

6.2.3.2.2.2. Dietary strategies used to meet body composition goals

Players provided an insight into their usual dietary behaviours surrounding a DXA scan. Players reported changes to DI behaviours including reductions made to CHO intake and excessive fluid intake particularly surrounding body composition assessment periods including the two weeks before a designated DXA scan. Furthermore, players discussed their dietary habits in the week prior to an assessment period with players reporting adjusting or removing CHO-rich foods from their diets. It was evident from discussions there was a constant compromise between consuming enough CHO for energy during training and ensuring intake supported body composition goals.

“…generally, in the weeks leading up, one to two weeks before a scan I cut out carbs a lot. Basically, almost that I am not eating CHOs at all because I do burn a lot of fat when I am doing that.”

“I would have shredded right up to the scan and drank a couple of litres of water right before, but I think I have become more relaxed in the last year”

“Less carb, more protein and vegetables”

“For dinner the night before I try to eat pretty light in the couple of days leading up, so I don’t feel too heavy. And then I keep really hydrated"

Players’ dietary habits were heavily influenced by the presence of body composition goals, with most of the changes made to habitual DI undertaken during periods where body composition was being assessed. Pressures experienced by players to meet body composition goals were reported, with many acknowledging that DI during these times did not represent usual intake. Players identified that DIs during these times may not be beneficial for their performance, recovery and health.

“…Because sometimes you can stress and the patterns you do throughout the year and patterns before a DXA can be unhealthy”.

6.2.3.2.2.3. Experienced players felt less pressure to meet body composition goals

Performance and training needs were the main drivers of food choice for experienced AF players. These players experienced less pressure surrounding body composition and used words such as ‘strong’ and ‘powerful’ when discussing their body composition goals. Experienced players provided insight into the presence of body composition goals within their team environment and the influence meeting these goals have had on their dietary patterns and performance in the past.

“Maybe a few years back it was about getting as low as you can be, and I don’t think that’s the best way to go about it.”

“…I was 10.4% [body fat] once and it’s such a fine line because I got to 10.4% in preseason and I was so light and didn’t have power in the contest but wasn’t getting applauded for how I was running.”

Experienced players identified a growing culture of support and understanding for their younger teammates, who experience greater levels of stress surrounding body composition assessment periods. Players spoke of the importance of performance on the field and further highlighted the importance of not removing CHO-rich foods, in order to meet their training and performance needs.

“*…I think it all needs to be around performance and performance in training. You can’t be eating less carbs and feeling flat at training.”*

Players reported difficulties in meeting body composition goals and dietary strategies used to alter body composition in order to reach these goals. Experienced players felt less pressure to meet body composition goals in comparison to young AF players. This suggests that more experienced players have a greater understanding of their body type, performance and diet and the impact body composition changes have on their performance. Additionally, younger players were more vulnerable to unsustainable dietary practices, with many developing their own body composition goals without expert advice.

6.2.3.2.2. Category two: Interpersonal Factors

Players provided insight into the interpersonal drivers behind food choice, many reporting social influences and relationships (i.e. family and peers) as main influences on food choice. Furthermore, players felt DI behaviours were influenced by changes in mood.

6.2.3.2.2.1. The influence of peers and family

When players felt supported by their family and peers (including teammates) they were more likely to demonstrate positive dietary behaviours associated with performance and recovery. Family members and partners were main influences on players' food choice. Players expressed that they were more likely to choose foods that did not align with their nutrition and performance goals if their social networks were not conducive to healthy eating.

> *"You come home, and your partner is eating burgers and chips and then you have to go and choose healthy things off the menu, it isn't going to work that well. It doesn't affect me as much because she [my partner] eats well."*

Players identified teammates as influences on their nutrition noting that team culture had a significant influence on their food choice, particularly around training sessions. Players that did not meet their body composition goals or did not choose foods related to their health and performance needs were viewed as unprofessional by their peers. Players experienced frustration when teammates failed to meet their specific body composition goal.

> *"Yeah I think that's the standard and what everyone expects and if you are not then you are not seen as professional."*

Players who struggled to reach their nutrition goals often found support from their teammates to meet these goals. Those who engaged in positive dietary behaviours, such as cooking within the home and meal preparation, felt these behaviours were influenced by the professionalism demonstrated by others. Players also reported that teammates were key sources of nutrition information and advice regarding optimal diet and dietary strategies.

"We have a fair few other players that also bring their lunch in. So, we hang out around the café, eat our food and have a cup of coffee up there."

"I lived with another player who was elite with his meal preparation. So, I think I learnt by living with him; whatever he was eating I was eating, and I learnt that way."

6.2.3.2.2.2. The influence of mood on food choice

Variations in mood appeared to influence players' food choice, with positive mood linked with greater motivation to meet nutrition goals and positive food behaviours. However, those that experienced low mood levels reported a lack of motivation to make positive food behaviours.

"...probably a big one is mood. Depends on the mood, if you are in a bad mood, I'll tend to eat bad food, if I'm in a good mood I'll probably stick to routine."

Peers, family and changes to mood were found to contribute to players' food choice and influence players' dietary behaviours. Taken together, players reported positive dietary behaviours and intakes when supported by their families and peers. Furthermore, changes in mood influenced players' food choice, with decreased mood associated with more discretionary food choices.

6.2.3.2.3. Category three: Stage of competition season (preseason and competition season)

Differences in training loads and nutrition motivations between the preseason and in-season were reported as influences on players' DIs. During the preseason, limiting factors such as appetite suppression post-training and limited time to eat on main training days were experienced by players. Additionally, during preseason, players perceived there was a greater focus on meeting body composition goals. In comparison, during the competition season players reported a greater focus on meeting nutrition needs for CHO, to ensure their match day performance and recovery needs were met.

6.2.3.2.3.1. Preseason influenced DI (i.e. reduced CHO intake)

During the preseason, players reported a variety of barriers to meeting nutrition goals with many reporting that greater training loads and intensities influenced appetite regulation post training. Appetite suppression was experienced post-training and identified as a barrier to recovery nutrition. Players reported difficulties meeting nutrition goals when training intensities and energy expenditures were high. Furthermore, difficulties with appetite (i.e. supressed appetite) were also experienced when temperatures during preseason were warmer than usual. However, overall volume of food consumed was reported as greater during the preseason period. Players reflected that most of their DI was consumed in the hours after training or on recovery days.

"Not straight after training. But when I'm in the car driving home because I have an hour's drive that's when I get hungry."

Limited time to eat during training days due to scheduled meetings and other commitments influenced players' recovery nutrition post-exercise. Players reported that nutrition post training was not a priority and that time made available to eat was limited.

"Yeah preseason training you are usually off to one thing and the next, sneaking food in when you can"

As noted earlier, body composition goals were also reported as a major focus during preseason with players reporting these goals as driven by staff and teammates. Players reported that without the presence of match-play and competition, body composition was used as a driver for their training and DI.

"Performance in preseason is like how you are physically but with games or in-season it's performance in games… So, you're judged on how you are looking and how you present in preseason and in-season it's how you play."

Whilst players reported pressures associated with meeting body composition goals, some reported that having a focus on their nutrition and body during preseason allowed them to maintain focus.

"In preseason it's nice to have a focus on your body and your nutrition as well because there aren't games to focus on so that's how you are performing, and I like that in preseason."

6.2.3.2.3.2. Competition season influenced DI (i.e. increased CHO intake).

The main dietary influences during the competition season were team selection and performance pressures, and the effects of high-intensity activity during games on appetite. Players reported that during the competition season, food choice was mostly made to complement competition performance and recovery needs. Players reported strategies such as CHO periodization and loading and monitoring of hydration to prepare for competition. Players reported that DI did not change surrounding body composition assessments during this time, with many reporting a greater consumption of CHO-rich foods during these periods.

"Depending on when we are training that's how I alter my CHO *intake…I eat more carbs in-season [competition season], just because I am more conscious of performance and recovery."*

"What fuel I need for game day, mainly around the carbs in-season. I think that's the main thing that changes are the carb periodization thing that the dietitian introduced and trying to get that right more often than not. That's the main reasoning why I eat the food I eat."

However, for those players needing to alter body composition during competition season, these goals were likely to impact their preparation and overall competition performance.

"I play better when I am relaxed, and not thinking about that kind of stuff [body composition]."

On competition days, players reported that feelings of nervousness and reduced appetite limited their DI prior to a match. Additionally, recovery nutrition post-match was influenced by a lack of appetite.

"I am hungry in the morning before training sessions, games are different. I don't really eat all that much."

"Yes definitely, initially [I have a lack of appetite after a match]. It will take me 2-3 hours to get something back in."

Food choice and dietary habits seemed to be driven by stage of competitions season, with more unsustainable dietary practices demonstrated during the preseason period. During competition season, players appeared to make food choices related to their performance and recovery needs, although match-day presented challenges around food intake.

6.2.3.2.4. Category four: Nutrition knowledge and support

6.2.3.2.4.1. Nutrition education and support services preferred by AF players

Players were asked about their preferred methods of nutrition services to help guide food choice and dietary habits. Individualised nutrition advice, which includes one-on-one consultations, was preferred in comparison to the provision of nutrition information via group education. Players felt best supported when nutrition advice was individualised to their needs, lifestyle and skill level e.g. cooking classes, label reading.

"One on one is good for me. In terms of learning the basics in a group is fine. But if you are trying to personalise training loads, diets and intakes, one on one is by far the best because everyone is different"

Experienced players acknowledged that nutrition in the past had been provided from a range of information sources. However, players felt sports dietitians in more recent times had a greater role in the provision of nutrition advice within the team sports environments.

"*100%, other staff would be all about BF percentage. Where the dietitian, is more like levelled with it all. Like getting enough carbs in and having a balanced diet, in comparison to always BF percentage."*

Players felt they had good nutrition knowledge; however, acknowledged that ongoing support and access to nutrition resources were important for their motivation. Furthermore, players felt greater support to keep on track and meet their nutrition goals when a sports nutrition professional was present within their sporting environment.

"If I have specific questions I like coming and asking [the dietitian] and that gets the convo going and it's more individually tailored."

Access to a sports nutrition professional can be a protective factor for the impact of body composition on dietary habits, especially for players that experience performance-related pressures. Those that felt supported to meet their nutrition goals appeared to make food related decisions based on their health and performance.

6.2.4. Discussion

6.2.4.1. General Findings

This study aimed to qualitatively explore factors influencing dietary habits and food choice of AF players. The secondary purpose was to explore players' dietary patterns prior to a body composition assessment. Players reported a range of factors that influence food choices and meeting their nutrition goals, the main influences included pressures to meet body composition goals and the role of peers and family (including partners). Individualised advice provided by a sports dietitian was perceived as the best source of nutrition of information and support.

6.2.4.2. Feelings and pressures associated with body composition goals

Pressures associated with meeting body composition goals were highlighted as a major influencing factor on AF players' nutrition choices. This finding is supported by previous qualitative research by Heaney, O'Connor (17) that reported body composition was also perceived as a barrier . In their study interviews were undertaken with a range of Australian athletes, coaches and sports dietitians and revealed that meeting body composition goals (i.e. physique) was a barrier to maintaining good nutrition (17). These interviews also showed that coaches were more concerned about body composition than players and sports dietitians (17). Interestingly, in the current study experienced AF players were less likely to be influenced by the presence of body composition goals, reporting match day performances and recovery as their main drivers for food choices and meeting their nutrition goals. Although previous research has not found significant differences in CHO and energy intakes between levels of playing experience (15, 18), Bilsborough et al. (2016) found that inexperienced AF players had significantly greater dietary fat intakes (18). Taken together, our findings suggest that younger or inexperienced players may be more vulnerable to unsustainable nutrition practices. This draws attention to the potential benefit of including experienced players in nutrition messaging and promoting a positive culture around food and performance. Furthermore, due to the presence of pressures related to body composition, nutrition education that specifically focuses on sustainable nutrition practices for body composition changes may be beneficial for those involved in the monitoring and development of body composition goals (i.e. high-performance teams and coaches). Success of nutrition education programs with sports specific staff, has been explored in a study by Jacob et al. (2016) who found that a theory-based nutrition intervention helped coaches to provide more accurate recommendations on sports nutrition (19). Furthermore, the inclusion of standardised protocols prior to body composition assessment may help to minimise error and promote sustainable nutrition practices prior to a DXA scan (20).

6.2.4.3. Dietary practices associated with adjusting or maintaining body composition

Maintaining optimal body composition – in particular the building and maintaining of FFSTM throughout a competitive season is important to reduce the risk of injury and illness and enhance performance (4). There is however limited research to quantify recommended body composition goals for AF players (15). What is known is the importance of FFSTM levels for strength and power, which are important characteristics to meet the physical demands of AF (10, 21). The use of body composition assessment methods such as DXA, may be warranted to provide professional players feedback on energy balance and changes to FFSTM (22). In this study, AF players reported adjusting CHO intake and/or removing CHO foods from their diet in the lead up to a body composition assessment, which may stem from misconceptions regarding the role of CHO for sports performance. Many players associated high CHO intakes with increased FM. The challenges of changing perceptions and misconceptions with regards to the amount of CHO required for team sports players has been highlighted in past research (8, 23, 24). International CHO recommendations have evolved in recent times, with greater focus on CHO periodisation strategies that focus on the timing and manipulation of CHO intake (24). Manipulating dietary CHO intake to align with training outputs can be a sustainable practice to adjust body composition and enhance training adaptations (23). Furthermore, it may be unnecessary for AF players to consume high CHO intakes (i.e. >8 $g \cdot kg^{-1} \cdot day^{-1}$) for consecutive training sessions without adjustments made for training outputs (23, 25). In the current study, those players who adopted strategies of CHO periodization reported more sustainable DI habits surrounding body composition assessment periods. To support sustainable DI, AF players may benefit from greater individualised advice with a focus on tailoring CHO intake to training demands. Future research into the development of realistic body composition goals for AF players may be beneficial for staff working with these players. Whilst realistic body composition goals are important for player wellbeing, goals should not overshadow the importance of consistent athlete monitoring and an individualised approach to nutrition.

6.2.4.4. Factors that influence DI of AF players (i.e. barriers to meeting nutrition goals, peers and family, preseason versus competition season changes)

The social act of eating and the surrounding environment may be as important as the advice and education provided to players to improve nutrition knowledge and support food choice (26). Peers and family (including teammates and partners) were perceived by players as one of the main influences on their food choice. Similarly, Trakman et al. (2019) found that 50% of Australian athletes (n=410) from a range of individual and team sports received nutrition information from family and friends, coaches and team-mates (27). Our findings suggest that families and teammates are sources of motivation for food choice, with many AF players reporting a greater ability to meet nutrition goals when supported by their teammates and families. An athlete's social network outside of the team environment can additionally support or hinder nutrition messages, particularly if players do not have the necessary knowledge and strategies to make informed food choices. To better support AF players' DIs outside of the team environment, future research should explore the effectiveness of nutrition education programs developed for families and peers, on players' ability to meet their nutrition goals. For vulnerable groups such as young or inexperienced players, building peer support around diet is essential and may be promoted by the inclusion of experienced players in nutrition messaging and education programs, with guidance from sports nutrition professionals

The influence of seasonal changes on AF players' DIs and body composition has been explored in previous research (18, 28). Typically, during the preseason training phase, decreases in FM and increases in FFSTM are observed. However, during the competition phase, the challenge is to maintain FFSTM gained during the preseason phase and mitigate against excessive increases in FM (18). Bilsborough et al. (2016) assessed the DIs of AF players over a season and found significantly greater dietary fat intakes at the start of preseason, with no differences in energy or CHO intake throughout the preseason and competition phases (18). During preseason there may be a greater focus on body composition, due to the absence of competition (i.e. match-day) and therefore limited available measures to assess performance. Furthermore, preseason will be an important period for players to prepare physically for competition success. Bradley et al. (2015) found that professional rugby union players had greater intakes of protein in preseason which exceeded recommendations (2.5-2.6 $g \cdot kg^{-1} \cdot day^{-1}$) as a result of players practising CHO periodization to optimise body composition (25). To avoid unwanted energy deficits that may arise from practices associated with adjusting body composition (i.e. manipulating CHO intake), a greater focus on individualised nutrition and tailoring intakes to training loads during preseason for this athletic population is recommended.

6.2.4.5. Feedback on the work of dietitians in the team sport environment and the importance of having individualised nutrition advice

Sports dietitians work to motivate and guide players to make food choices that align with performance and recovery demands. Whilst the capacity for sports nutrition professionals in team sport environments may be limited due to economic and time constraints (17), many players report having access to advice and information from a sports dietitian or nutritionist to some degree (27, 29-31). Due to the aforementioned constraints, an understanding of the nutrition services desired

Table 20. A summary of categories, sub-categories and themes identified from semi-structured interviews.

Research Question	Categories	Sub-categories	Themes
What factors influence food choice and dietary behaviours of AF players'	1. Body composition	*1.1. Perceived pressures associated with body composition assessment and goals*	- *Players feel pressure from Peers, High performance teams, S&C, coach to meet body composition goals*
		1.2. Dietary strategies used to meet body composition goals	- *Players modify DI leading up to DXA by restricting* CHO *and/or discretionary foods and manipulating fluid intake*
		1.3. Experienced AF players felt less pressure meeting body composition	- *Experienced players feel less pressure to achieve body composition goals and focus more on performance*
	2. Interpersonal factors (i.e. peers, family and access)	*2.1. The influence of peers and family*	- *When players felt supported by their relationships to make healthy food choices, they were more likely to make positive food choices related to health*
		2.2. The influence of mood on food choice	- *Players that felt decreased mood levels had a lack of motivation to make positive food choices*
	3. Stage of competition season (i.e. in season versus preseason)	3.1. *Preseason influenced DI (i.e. reduced CHO intake)*	- *Players felt more pressure to meet body composition goals during preseason and reduced intake of CHO surrounding DXA scans* - *A lack time on main training days negatively influenced DI*
		3.2. Competition season influenced DI (i.e. increased CHO intake)	- *Players reported a greater intake of CHO during competition season* - *Players experienced suppressed appetite post competition matches*
	4. Nutrition knowledge and support	*4.1. Nutrition education and intervention preferred by AF players*	- *Players prefer individual dietetic consultations to group presentations* - *Players feel they have good nutrition knowledge and are not seeking specific nutrition information*

Abbreviations: S&C: Strength and Conditioning, DI; Dietary intake, DXA: Dual Energy X-ray Absorptiometry, CHO; Carbohydrate, AF: Australian Football

Figure 7. Factors that influence AF players' personal food choice

Abbreviations: AF: Australian Football by players and teams can be beneficial to advocate for nutrition services in team sport environments. In this study, AF players favoured working one on one with a sports dietitian, in comparison to the provision of nutrition services via group education (including cooking programs) and information sources (i.e. internet). The benefits of tailored advice to support players' nutrition goals has been established, with significant changes to players' DIs with increases in CHO and protein intake and NK observed after completion of an individualised nutrition counselling program (32). Furthermore, positive associations have been observed between DI and access to a sports dietitian, with Hull et al. (2017) reporting significant differences between DI of players who worked with a sports dietitian compared to those who did not (33, 34). Players who reported receiving regular advice from a sports dietitian had reduced fast food intake, more regular pre-training breakfast intake and prepared more meals at home (34). Taken together these findings suggest that providing access to a sports nutrition professional may improve adherence to sustainable nutrition practices; however, more research regarding efficacy of education methods to improve AF play DIs required.

6.2.4.6. Limitations

The nature of the cohort included in this study (i.e. small sample size and recruited from one club) may limit generalisability of results. However, researchers observed a redundancy in information obtained within the 12 interviews, suggesting data saturation was achieved and no further interviews were required. This study only included male AF players, so more research is required to explore female AF players' perceptions of nutrition, body composition and type of nutrition services preferred. With only one researcher (SJ) conducting interviews with players, interview bias was highlighted as a potential confounding factor when developing the study design, It was potentially beneficial that the interviewer was connected directly with the players in the club environment, improving the candour of the responses due to previously established relationships. However, due to the interviewer's affiliation with the club, it may have also limited players' responses including voicing concerns and providing feedback. The 'Pygmalion effect' described by Rosenthal and Jacobson (1986) is a theory used to describe the phenomena whereby expectations of an individual may influence the responses collected, therefore with regards to our research, responses may have been influenced by the presence of the team dietitian who collected interview responses (35). To reduce the risk of confirmation bias, a separate researcher (AF) was included in the analysis of data collected and the development of categories and themes. Despite these limitations, this study provides the first insight into professional AF players' perceptions of factors influencing food choice and provides feedback on the presence of a sports dietitian in a professional team sport environment.

6.2.4.7. Summary of key findings

Whilst many AF players understand the importance of good nutrition practices, the pressure of meeting body composition goals and the influence of peers and family were acknowledged as influences on their DI and meeting nutrition goals. During times where body composition was being assessed, players reported their CHO intake decreased in the weeks, and fluid intake increased in the days prior to a DXA scan. However, during the competition season these habits were not sustained, as DI of CHO was increased to meet demands of competition and recovery. Players highlighted that individualised advice, provided by one-on-one consults with a sports dietitian was their preferred nutrition service.

6.2.4.8. Recommendations for practice

Younger or inexperienced AF players were found to be more likely to report changes in Dis surrounding body composition assessment periods and therefore may require additional support to ensure food choice meets performance and recovery goals. To further promote messages related to healthy eating behaviours and positive culture surrounding body composition, dietitians may aim to include experienced players as a support tool in nutrition education programs. Nutrition education regarding the importance of periodised CHO intake for performance and the impact of body composition pressures on players may also be beneficial for the support staff involved in the development of body composition goals.

6.2.4.9. Recommendations for future research

More research is required to explore efficacy of nutrition services and types of education methods that improve DI and inform healthy food choice within the team sport environment. There is also a need to expand on this work with a wider cohort of players drawn from other AF clubs, including female AF players to confirm that the barriers players experience to meeting their nutrition goals observed in this playing group are applicable across the competition.

References

1. Bisogni C, Connors M, Devine C, Sobal J. Who We Are and How We Eat: A Qualitative Study of Identities in Food Choice. Journal of Nutrition Education and Behavior. 2002;34(3):128-139.
2. Long D, Perry C, Unruh S, Lewis N, Stanek-Krogstrand K. Personal food systems of male collegiate football players: a grounded theory investigation. Journal of athletic training. 2011;46(6):688-695.
3. Birkenhead K, Slater G. A Review of Factors Influencing Athletes' Food Choices. Sports Medicine. 2015;45(11):1511-1522.
4. Thomas D, Erdman K, Burke L. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine in Science in Sports and Exercise. 2016;48(3):543-568.
5. Kerksick C, Arent S, Schoenfeld B, Stout J, Campbell B, Wilborn C, et al. International society of sports nutrition position stand: Nutrient timing. Journal of the International Society of Sports Nutrition. 2017;14(1).
6. Impey S, Hearris M, Hammond K, Bartlett J, Louis J, Close G, et al. Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis. Sports Medicine. 2018;48(5):1031-1048.
7. Kerksick C, Wilborn C, Roberts M, Smith-Ryan A, Kleiner S, Jäger R, Collins R, Cooke M, Davis J, Galvan E, Greenwood M, Lowery L, Wildman R, Antonio J, Krieder R. ISSN exercise & sports nutrition review update: research & recommendations. Journal of the International Society of Sports Nutrition. 2018;15(1):38.
8. Jenner S, Buckley G, Belski R, Devlin B, Forsyth A. Dietary Intakes of Professional and Semi-Professional Team Sport Athletes Do Not Meet Sport Nutrition Recommendations—A Systematic Literature Review. Nutrients. 2019;11(5):1160.
9. Holway F, Spriet L. Sport-specific nutrition: Practical strategies for team sports. Journal of Sports Sciences. 2011;29:115-125.
10. Johnston R, Black G, Harrison P, Murray N, Austin D. Applied Sport Science of Australian Football: A Systematic Review. Sports Medicine. 2018;48(7):1673-1694.

11. Trakman G, Forsyth A, Devlin B, Belski R. A Systematic Review of Athletes' and Coaches' Nutrition Knowledge and Reflections on the Quality of Current Nutrition Knowledge Measures. Nutrients. 2016;8(9):570.
12. Tam R, Beck K, Manore M, Gifford J, Flood V, O'Connor H. Effectiveness of Education Interventions Designed to Improve Nutrition Knowledge in Athletes: A Systematic Review. Sports Medicine. 2019;49(11):1769-1786.
13. Burke L. Dual X-Ray Absorptiometry (DXA) for measurement of body composition in athletes: Experiences that underpin the importance of optimising the reliability of measurement. Journal of Science and Medicine in Sport. 2017;20:76.
14. DeCarlo M. Scientific Inquiry in Social Work. Scientific Inquiry in Social Work. 2018.
15. Jenner S, Trakman G, Coutts A, Kempton T, Ryan S, Forsyth A, Belski, R. Dietary intake of professional Australian football athletes surrounding body composition assessment. Journal of the International Society of Sports Nutrition. 2018;15(1).
16. Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;3(2):77-101.
17. Heaney S, O'Connor H, Naughton G, Gifford J. Towards an Understanding of the Barriers to Good Nutrition for Elite Athletes. International Journal of Sports Science & Coaching. 2008;3(3):391-401.
18. Bilsborough J, Greenway K, Livingston S, Cordy J, Coutts A. Changes in anthropometry, upper-body strength, and nutrient intake in professional Australian football players during a season. International Journal of Sports Physiology and Performance. 2016;11(3):290-300.
19. Jacob R, Lamarche B, Provencher V, Laramée C, Valois P, Goulet C, et al. Evaluation of a Theory-Based Intervention Aimed at Improving Coaches' Recommendations on Sports Nutrition to Their Athletes. Journal of the Academy of Nutrition and Dietetics. 2016;116(8):1308-1315.
20. Nana A, Slater G, Hopkins W, Halson SL, Martin DT, West N, Burke L. Importance of standardized DXA protocol for assessing physique changes in athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2016;26(3):259-267.

21. Bilsborough J, Kempton T, Greenway K, Cordy J, Coutts A. Longitudinal changes and seasonal variation in body composition in professional Australian football players. International Journal of Sports Physiology and Performance. 2017;12(1):10-17.
22. Bartlett J, Hatfield M, Parker B, Roberts L, Minahan C, Morton J, et al. DXA-derived estimates of energy balance and its relationship with changes in body composition across a season in team sport athletes. European Journal of Sport Science. 2019:1-9.
23. Burke L, Hawley J. Swifter, higher, stronger: What's on the menu? Science. 2018;362(6416):781-787.
24. Burke L, Hawley J, Jeukendrup A, Morton J, Stellingwerff T, Maughan R. Toward a Common Understanding of Diet–Exercise Strategies to Manipulate Fuel Availability for Training and Competition Preparation in Endurance Sport. International Journal of Sport Nutrition and Exercise Metabolism. 2018;28(5):451-463.
25. Bradley W, Cavanagh B, Douglas W, Donovan T, Twist C, Morton J, Close G. Energy intake and expenditure assessed 'in-season' in an elite European rugby union squad. European Journal of Sport Science. 2015;15(6):469-479.
26. Contento I, Williams S, Michela J, Franklin A. Understanding the food choice process of adolescents in the context of family and friends. Journal of Adolescent Health. 2006;38(5):575-582.
27. Trakman G, Forsyth A, Hoye R, Belski R. Australian team sport athletes prefer dietitians, the internet and nutritionists for sports nutrition information. Journal of Nutritrion and Dietetics. 2019:1-10.
28. Devlin B, Leveritt M, Kingsley M, Belski R. Dietary intake, body composition, and nutrition knowledge of Australian football and soccer players: Implications for sports nutrition professionals in practice. International Journal of Sport Nutrition and Exercise Metabolism. 2017;27(2):130-138.
29. Devlin B, Belski R. Exploring General and Sports Nutrition and Food Knowledge in Elite Male Australian Athletes. International journal of sport nutrition and exercise metabolism. 2015;25(3):225.

30. Andrews M, Itsiopoulos C. Room for Improvement in Nutrition Knowledge and Dietary Intake of Male Football (Soccer) Players in Australia. International Journal of Sport Nutrition & Exercise Metabolism. 2016;26(1):55-64.
31. Lohman R, Carr A, Condo D. Nutritional Intake in Australian Football Players: Sports Nutrition Knowledge and Macronutrient and Micronutrient Intake. International Journal of Sports Nutrition and Exercise Metabolism. 2019. 29(3):289-296.
32. Valliant M, Emplaincourt H, Wenzel R, Garner B. Nutrition Education by a Registered Dietitian Improves Dietary Intake and Nutrition Knowledge of a NCAA Female Volleyball Team. Nutrients. 2012;4(6):506-516.
33. Hull M, Jagim A, Oliver J, Greenwood M, Busteed D, Jones M. Gender differences and access to a sports dietitian influence dietary habits of collegiate athletes. Journal of the International Society of Sports Nutrition. 2016;13(1).
34. Hull M, Neddo J, Jagim A, Oliver J, Greenwood M, Jones M. Availability of a sports dietitian may lead to improved performance and recovery of NCAA division I baseball athletes. Journal of the International Society of Sports Nutrition. 2017;14:29.
35. Rosenthal R, Jacobson L. Pygmalion in the classroom. The Urban Review. 1968;3(1):16-20.

CHAPTER SEVEN

7.1. Summary of Findings and Practical Applications

Using practice based and applied research, this PhD project aimed to provide an assessment of the DIs and NK of professional AF athletes and explore factors influencing male AF athletes' dietary behaviours and food choice. The following section provides a summary of findings and suggests strategies to translate research findings into practical recommendations for use within AF and team sport environments.

Key finding #1: Energy and CHO intakes of AF athletes do not align with sports nutrition recommendations.

Food records (i.e. three and seven day) were used to assess the DIs of professional female (Chapter Five) and male AF athletes (Chapter Four), respectively (1, 2). Despite the need for energy and CHO intakes that match training and performance demands, a nutritional analysis of reported DIs did not align with recent recommendations advocated by the ISSN (1-3). Currently, sports nutrition recommendations such as those outlined by the ISSN provide broad guidelines for energy and macronutrient intakes. This is due to the need to consider the dietary requirements of a range of different individual and team sport athletes (3). When sports nutrition recommendations are used without knowledge of the different physical demands of individual and team based sports, dietary advice provided to athletes may be limited (3). Therefore, it is essential sports nutrition professionals have an in-depth understanding of athletes' training and competition physiological demands, to ensure dietary advice effectively translates and applies broad recommendations into practice (3, 4).

Within the AFL every team will have different periodised training loads and will provide individualised athlete performance goals. In Chapter Two, strategies such as 'Fuel for the work required' were highlighted as a potentially superior dietary strategy to use within AF environments to allow dietary recommendations to accommodate differences in training and competition demands

(5, 6). Therefore to assess whether AF athletes take a periodised approach towards nutrition, AF athletes' DIs were assessed across a training week (of different training loads) and were compared against training loads recorded using GPS (1, 2). In particular, an analysis of food records found the highest CHO intakes recorded on light training days, which was followed by main training and recovery days (1, 2). These results identify that CHO intakes were not periodised according to training demands (1, 2). To ensure DIs are tailored correctly to training loads performed, it is essential sports nutrition professionals work collaboratively with high performance teams (i.e. sports scientists, strength and conditioning coaches etc.) to provide a better understanding of work-loads (i.e. GPS, strength training) (7). Working collaboratively as a part of a multi-disciplinary team, ensures that dietary advice provided to athletes is also aligned with athletes' overall performance goals. To promote collaboration, it may be beneficial for sports nutrition professionals to be embedded within high-performance teams. By doing so, sports nutrition professionals can build rapport and the overall perspective of the role of the sports nutrition professional can be enhanced (8). Furthermore, greater access to tailored dietary advice may help to support improvements in DI, especially surrounding training sessions where adaptations and performance outcomes are required. (3, 4).

Research findings suggest that AF athletes require individualised dietary planning that focuses on the manipulation of CHO availability according to training loads, as many reported intakes fell below CHO recommendations advocated for skill-based sports (3-5 $g^{-1}\cdot day^{-1}$) (3). Due to the aerobic and high-intensity nature of AF competition and training, current CHO intakes reported by AF athletes may be seen as inadequate to support the optimisation of glycogen stores required for aerobic performance and recovery, especially when total distance and overall training demands are high (e.g. during the preseason) (6, 7, 9). In particular, dietary manipulation strategies such as 'Fuel for the work required' and 'Train low, compete high' which have been used with endurance athletes to optimise work efficiency and increase training adaptations, may be seen as beneficial for use within AF, whereby CHO intakes are tailored and manipulated according to individual athlete training loads (6, 10, 11).

To build on the findings in Chapter Four, further research was undertaken to explore the behavioural practices of AF athletes. It was hypothesised that male AF athletes' CHO intake was influenced by pressures associated with meeting body composition goals. This hypothesis was supported by the presence of the body composition assessments (i.e. DXA scan) during the data collection (i.e. food record) period (2). Similarly, previous literature as identified that many team sport athletes also do not meet recommended CHO targets, with body composition identified has a potential influence on the consumption of CHO based foods (12, 13).

To explore these phenomena further, qualitative research (Chapter Six) in the form of semi-structured interviews was undertaken with a group of professional male AF athletes. Interviews revealed that meeting body composition goals was perceived as a barrier to meeting nutrition goals, especially those related to CHO. Younger or inexperienced athletes reported changes to their dietary habits prior to a DXA scan, which included the removal or reduction of CHO foods from their diet. In comparison, experienced athletes perceived less pressure to meet body composition goals and identified that performance and recovery were the main drivers of their food choice. As a result of this research it can be suggested that younger or inexperienced AF athletes associate CHO intakes with increased FM and have limited knowledge regarding the link between CHO and performance. Nutrition education that focuses on the link between nutrition and performance may be beneficial for younger or inexperienced athletes, who are vulnerable to body composition pressures and engage in unsustainable dietary patterns as a result. Given that experienced athletes' perceived performance and recovery are the main drivers for meeting nutrition goals, it may be beneficial to include experienced athletes as a resource and in the delivery of nutrition messages within education programs provided to younger athletes. Taken together this research highlights the importance of promoting healthy cultures surrounding food and body composition and identifies the influence these body composition goals have on athletes in relation to meeting their nutrition goals. Therefore, it is integral that support staff such as sports nutrition professionals (i.e. SDs), psychologists and medical teams (i.e. GPs) play a leading role in the monitoring of body composition and advocate for athlete health and wellbeing. Furthermore, all staff within professional sport environments should aim to work collaboratively and focus on the adoption of a player centred approach, when developing body composition goals. Education regarding the influence body composition has on athletes meeting their nutrition goals may be beneficial for those staff involved in the development of goals and may additionally help to promote team cultures that drive nutrition for performance.

Practical applications

- Sports nutrition professionals working within team sport should ensure dietary advice is suited to an athlete's training and competition physiological demands.
- Sports nutrition professionals should work collaboratively with high performance staff to build rapport and to ensure dietary advice aligns with training and performance goals.
- Dietary manipulation strategies such as 'Fuel for the work required' may be suitable for use within AF to periodise intake to differing training loads and to promote training adaptations.
- To promote supportive cultures surrounding body composition, sports nutrition professionals should aim to build rapport with experienced athletes and include them in nutrition messaging to younger athletes.

Key finding #2: AF athletes have 'poor' to 'average' nutrition knowledge

Australian Football athletes' NK was assessed using a validated questionnaire (i.e. NSKQ). Questionnaires highlighted that male and female AF athletes have 'poor' to 'average' NK as per the validated scale (2, 14). Both male and female AF athletes included performed poorly in the micronutrient, sports nutrition and supplements subsections of the NSKQ and male AF athletes also had 'poor' NK in the weight management subsection (2, 14). Research presented in Chapter Two, has identified weak but positive relationships between DI and NK (2, 14, 15). Therefore, it may be suggested that if tailored nutrition education is focussed on AF athletes' specific knowledge gaps, athletes' Dis may be improved (2, 14, 15).

Male AF athletes may benefit from nutrition education that focusses on the link between nutrition and performance to promote improvements in knowledge and to support DIs that are performance driven (2). Due to currently reported suboptimal DIs (i.e. no periodisation, low CHO intakes) and reported use of unsustainable dietary strategies to meet body composition goals, nutrition education that focuses on weight management and sports nutrition strategies such as CHO periodisation, may be important and is aligned with observed NK gaps (2). Similarly, to better align professional female AF athletes' DIs, nutrition education that focuses on sports nutrition principles such as energy intake and CHO periodisation may be beneficial (14). Furthermore, for female AF athletes, additional nutrition education may also need to focus on the importance of calcium and iron for overall health and prevention of injury and illness, to support dietary planning that aims to improve their intake of these micronutrients. (1, 14).

Whilst there are similarities in knowledge gaps between male and female AF athletes, research highlights that the mode and delivery of education provided regardless of gender should be tailored according to the overall team environment. Additionally, wherever possible, nutrition education should be tailored according to athletes' NK needs, which can be assessed using a NK assessment tool such as the NSKQ (16). While individualised nutrition advice is still preferred, one-on-one advice may be limited by the constraints of the club environment and athletes' personal commitments (i.e. train on a part-time basis). Therefore, group-based nutrition education strategies may be used as a time and cost-effective strategy to support improvements in NK and to positively influence dietary habits. Furthermore, the provision of sport specific nutrition information via online platforms such as mobile applications and social media may be useful way to capture athletes who spend limited time within the club environment (i.e. female AF athletes, long term rehabilitation athletes). Taken together, strategic nutrition education that focuses on improving NK gaps, may be a low cost and time effective way to provide nutrition intervention within team sport environments, where challenges such as limited time and access to athletes are experienced.

Practical applications

- NK assessment tools such as the NSKQ can be used to identify NK gaps and tailor education according to athletes' NK needs.
- Greater access to nutrition support (i.e. nutrition education and individual consults) may be beneficial at junior and academy AF levels, to ensure younger athletes have a sound

knowledge of nutrition fundamentals before transitioning to the professional level.

- Male AF athletes may benefit from nutrition education that focusses on sports nutrition principles linked to performance, such as CHO periodization, and sustainable weight management.
- Female AF athletes may benefit from nutrition education that focusses on sports nutrition principles such as CHO periodisation and the importance of calcium and iron for overall health.

Key finding #3: AF athletes' food choice is complex and can be influenced by a range of individual factors

Decisions behind food choice were explored using a qualitative approach (Chapter Five). Findings suggest that dietary practices reported by male AF athletes, were influenced by a variety of individual factors. Body composition pressures, seasonal changes (i.e. preseason versus competition season), interpersonal factors and access to nutrition professionals, were highlighted as major influences on food choice. Social environments (i.e. family support) and positive team cultures, were found to support AF athletes meeting their nutrition and performance goals, however the pressure of meeting body composition goals was a barrier. AF athletes' families and partners were perceived as a main source of support outside of the team environment. Therefore, sports nutrition professionals may see the benefit of providing nutrition education and advice to athletes' families, to ensure food choices made outside of the team environment align with athletes' performance goals.

Team culture was identified as a driver for many athletes, especially when meeting a clear body composition goal. It was also evident that younger athletes were influenced by the surrounding team culture. It was clear that if team culture did not support sustainable nutrition practices related to body composition, DI was negatively impacted. Therefore, to promote positive cultures surrounding body composition, sports nutrition professionals should focus on development of rapport with experienced or older athletes to ensure messages related to nutrition are aligned and as a way to positively influence younger, less experienced athletes. Given that a variety of staff often are involved in the development of athletes' body composition goals, an evidence-based approach is essential and rigid targets established for teams should be avoided. A multi-disciplinary approach to decision making with regards to body composition can ensure individual athlete needs are considered. Coaches and other support staff may be influential in

Sports nutrition professionals play a key role in the development of individualised body composition goals; however, it is important that dietary advice is not limited simply to that focussed on manipulation of body composition and that the role between nutrition and performance is also considered and prioritised.

Practical applications

- To support AF athletes' food choice outside of team environments, sports nutrition professionals may see benefit in the provision of nutrition advice and education to athletes' families and partners.
- When developing body composition goals, it is essential that a multi-disciplinary approach is undertaken to ensure athletes' needs are considered.
- Dietary advice should not be limited simply to that focussed on manipulation of body composition and the role between nutrition and performance should be considered and prioritised.

Key finding #4: An individualised approach to professional nutrition input is essential

A mixed-methods approach using questionnaires (Chapters Four and Five) and semi-structured interviews (Chapter Six) enabled the identification of perceptions related to nutrition services including AF athletes' preferred mode and source of nutrition information (2, 14). It was evident that AF athletes supported the work of sports nutrition professionals, highlighting their preference for one-on-one consults with a sports dietitian (2, 14). In addition, qualitative research included in Chapter Six, revealed male AF athletes felt best supported when dietary advice was tailored to their own individual training needs, goals and considered their external environments. To promote energy and CHO intakes that are consistent with training needs, male and female AF athletes would benefit from dietary strategies that guide the periodisation of DIs (1, 2). Having a sports nutrition professional embedded within high performance teams, can improve access to individualised dietary advice. By simply increasing presence, sports nutrition professionals have the ability to build rapport with athletes which is integral to support improvements to dietary practices. Additionally, increasing the presence sports nutrition professionals to more than 1-2 days a week (i.e. changing from part-time to full-time) within team environments, may help to motivate changes towards dietary behaviours that are better aligned with performance goals and ensure dietary advice provided to athletes is translated into practice (17).

Practical applications

- Team sport environments may see benefit in embedding sports nutrition professionals within high performance teams, to provide athletes with greater access to tailored dietary advice and to ensure intent and knowledge translates into practice.

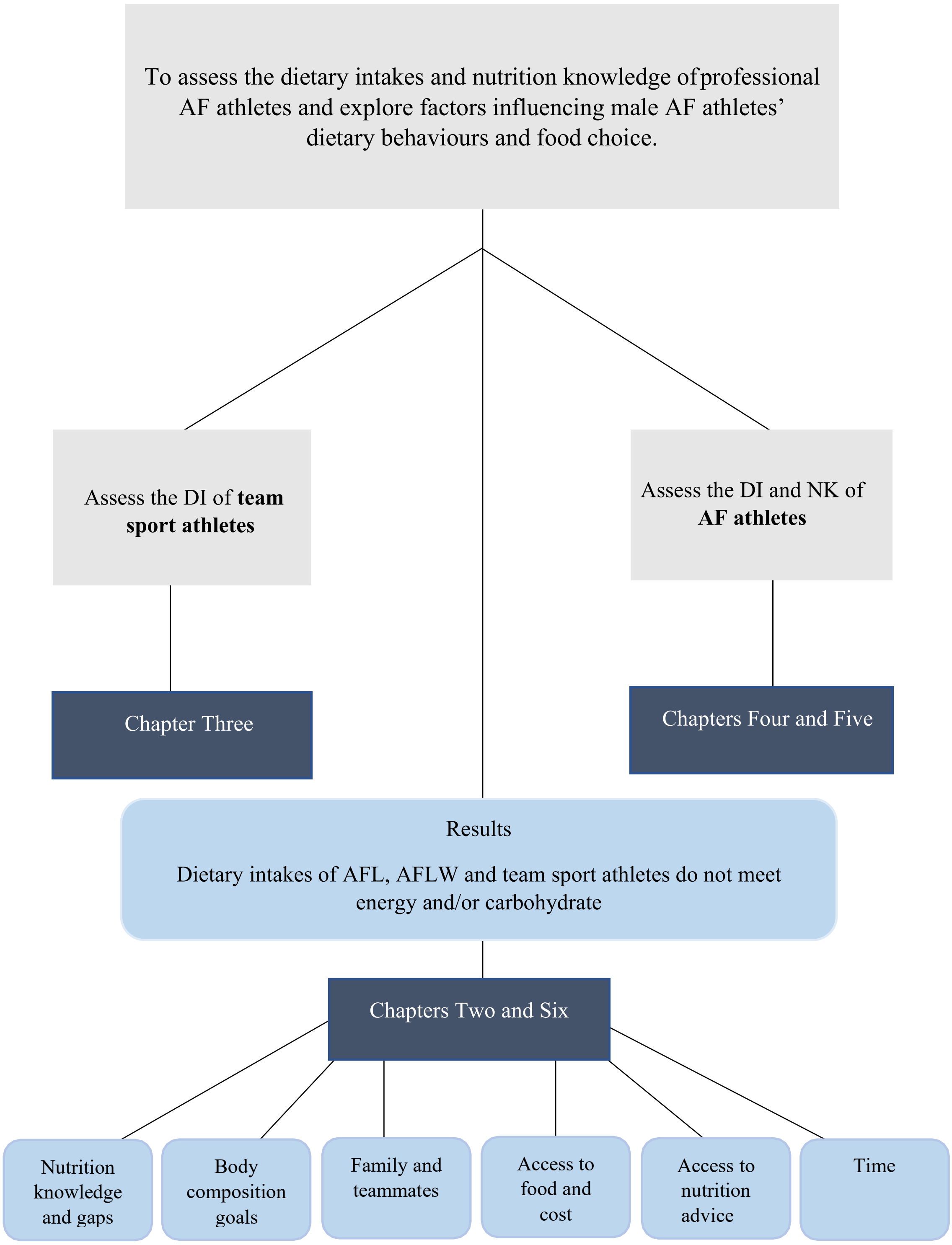

Figure 8. Aims of PhD research and a summary of main research findings

Table 21. Summary of PhD research and main findings

Chapter	Title	Journal	Participants	Study type/design	Data collection	Main findings
Chapter 3	Dietary intakes of professional and semi-professional team sport athletes do not meet sport nutrition recommendations—A systematic literature review. (12)	Nutrients (2019)	Professional and Semi-professional team sport athletes (n=511)	Systematic literature review	DI: Food records (i.e. 3, 4, 6- and 7-days food record), Food recalls (i.e. 24 hr and 72 hr recall), weighed food diary (i.e. 4 days)	• Most team sport athletes reported DI that exceeded sports nutrition recommendations for protein and/or fat, not for energy and CHO.
Chapter 4	Dietary intake of professional Australian Football athletes surrounding a body composition assessment. (2)	Journal of the International Society of Sports Nutrition (2018)	Professional male AF athletes (n=46)	Quantitative, Cross sectional design	DI: Food records (7-day food record) NK: NSKQ Body composition: DXA	• No athlete included met energy and CHO recommendations (2.4 ± 0.9 $g \cdot kg^{-1} \cdot day^{-1}$). • NK scores were positively associated with energy ($r^2 = 0.33$, $P = 0.03$), protein ($r^2 = 0.35$, $P = 0.02$), fibre ($r^2 = 0.51$, $P = 0.001$) and calcium intakes ($r^2 = 0.43$, $P = 0.004$). • AF athletes had 'poor' NK (46% mean score) specifically in weight management, sports nutrition, micronutrient and supplements subsections. • Using Goldberg equations, the majority (78%) of athletes were classed as under-reporters of DI.
Chapter 5	Dietary intakes of professional Australian Football League Women's (AFLW) athletes during a preseason training week. (1)	Journal of Science and Medicine in Sport (2019)	Professional female AF athletes (n=23)	Quantitative, Cross sectional design	DI: Food records (3 day)	• Most athletes did not meet CHO (95%), iron (87%) and calcium (61%) recommendations. • No significant difference was found in energy and CHO intake on main training, light training and recovery days ($P>0.05$)
Chapter 5	Assessing the nutrition knowledge of professional Australian Football league	Journal of Science and Medicine in	Professional female AF athletes (n=26)	Quantitative, Cross sectional design	NK: NSKQ	• Athletes had 'average' NK (50.6%)

	Women’s (AFLW) athletes. (14)	Football (2020)				• Athletes performed poorly in micronutrients, sports nutrition and supplement subsections. • Significant positive associations were found between NK and age (P<0.05), education (P<0.05) and prior study in human nutrition (P<0.05).
Chapter 6	A qualitative investigation of factors influencing the DIs of professional Australian Football athletes’	Sports medicine *(2020- under review)*	Professional male AF athletes (n=12)	Qualitative, Cross sectional design	Semi-structured interviews	• The presence of body composition goals was perceived by younger, inexperienced athletes as a barrier to DIs which would enable the meeting of nutrition goals. • Many athletes reported dietary manipulation strategies such as reducing CHO intake and excessive fluid intake, in the weeks and days prior to a DXA scan. • Athletes reported families and peers had a major influence on their food choice, especially outside of the club environment.

Abbreviations: *Dietary intake; DI, Australian Football; AF, Carbohydrate; CHO, Nutrition Knowledge; NK, Nutrition for Sport Knowledge Questionnaire; NSKQ*

7.2. Future Directions

Research that has been undertaken as a part of this PhD project has identified a variety of future research opportunities not only within AF environments, but within a range of team sports. Research undertaken as a part of this PhD highlights the value AF athletes place on an individualised approach, in comparison to other modes of nutrition education (i.e. group education, cooking programs etc.).

7.2.1. Assess the efficacy of nutrition education and support within professional team sport

Nutrition education can support improvements in NK, which is a known modifiable determinant of DI (15). Given that many sports nutrition professionals have limited access to athletes, there is a need for research to quantitatively identify the types of nutrition education that best supports dietary behaviour change, so that limited time with athletes can be used most effectively.

Challenges, such as time constraints and limited access within club environments, will limit AF athletes' access to face to face nutrition education and dietary advice. Online platforms and applications may be a useful nutrition education strategy to support improvements in AF athletes' NK and to positively influence dietary habits (18, 19). Increased self-efficacy and motivation to change, have been observed with internet based education programs in both athletic and non-athletic populations (20-22). In particular, a pilot study by Simpson et al., (2017) assessed the use of a smart phone application (Meal Logger®) with professional male field hockey athletes (n=17) (22). Using a novel approach, Simpson et al. (2017) found improvements in athletes' NK (P=0.01) and attitudes related to DI behaviours (22). Whilst these findings highlight the potential benefits of using online education programs, limited research has assessed the use of technology based education programs with athletic cohorts (19). Therefore, future research should assess the efficacy of online platforms for the provision of nutrition education with professional athletes including AF athletes. Within environments where access to athletes is limited (i.e. female AF athletes, long term rehabilitation) time effective education strategies that can improve NK and dietary habits- warrants further exploration.

Furthermore, Chapter Six highlighted that younger or inexperienced athletes were more vulnerable to partaking in unsustainable dietary practices (i.e. removing CHO foods). Therefore, nutrition education regarding the link between nutrition and performance may be important to improve NK and drive sustainable dietary practices. Qualitative research undertaken with male AF athletes suggested that to promote a supportive team culture around nutrition and body composition, sports nutrition professionals may see benefit in the inclusion of experienced or older athletes in the delivery of nutrition messages and as a resource in nutrition education programs. The influence of teammates on athletes' DIs has been additionally highlighted by previous research including the work of Birkenhead and Slater (2016) (23). Taken together, future research is required to assess the efficacy of nutrition education strategies that include experienced athletes as a resource and their influence on the dietary practices and NK of younger athletes' (23).

7.2.2. Incorporating a mixed methods approach when assessing athletes' DIs

Qualitative research undertaken with professional male AF athletes (Chapter Six) highlights that food choice is complex and is influenced by a range of factors. It was evident from this research that combining DI data with a qualitative exploration provided a valuable insight into athletes' food choice. The mixed methods approach also identified how dietary intervention could help support athletes in meeting their nutrition goals. Similarly, research by Ono et al (2012) combined qualitative (i.e. interviews) and quantitative (i.e. food record) research methods, to assess professional football athletes' DIs and explore drivers and barriers behind their food choice (24). The authors found that professional football athletes reported suboptimal DIs and via the interviews were able to get further insight and identify that the team culture and individual athlete upbringings were likely factors influencing athletes' DIs (24). Therefore, research that employs a mixed methods approach may be useful to provide an insight into the decisions made around food and may be useful when planning dietary strategies to support behaviour change. Therefore, when aiming to assess professional athletes' DIs, future research should aim to use a mixed methods approach. Using both quantitative and qualitative research methods can help to translate research findings into practical recommendations and can provide an overall assessment of athletes' DIs, NK and barriers to meeting nutrition goals. Future research is required to qualitatively assess the factors that influence professional female AF athletes' DIs (25).

7.2.3. The development of sport-specific body composition ranges

Pressures associated with meeting body composition goals were reported by younger AF athletes and are likely the result of the need to physically prepare athletes for AF competition and to prevent injury. For AF athletes there is a focus on enhancing FFSTM relative to BF, in order to promote important physical attributes such as power and agility, which are required for competition (4). Furthermore, research by Bilsborough et al. (2018) identified that younger AF athletes on average have lower amounts of body mass, bone mineral content and FFSTM, when compared to experienced AF athletes (26). Therefore, to physically prepare athletes, there is a need to focus training programs and nutrition advice on developing FFSTM (26). (27). For younger athletes exposure to professional match-play is now being observed much earlier than before and as a result longer timeframes that were once available to promote development, are usually fast tracked with the perception that it may prevent injury and fatigue during the competition season (28). Pressures to meet body composition goals within short time periods, may increase the likelihood of unsustainable dietary behaviours and without proper dietary planning may impair performance and influence overall health (27). Given that younger AF athletes have reported pressures associated with meeting targets, it is imperative that the goals developed are individualised and wherever possible one-fits-all rigid targets are avoided (29).

Currently, there is limited research exploring associations between body composition and performance in AF. Therefore, it may be suggested that goals developed for AF athletes may not be evidence based. In comparison, research undertaken in professional football has explored relationships between anthropometry and aspects of performance, to provide a useful guide for those involved in the development of body composition goals (30-32). Therefore, to promote best practice in this area, there is a need for research to explore relationships between body composition (i.e. FFSTM and BF) and performance outcomes in AF specifically. This research could then be used to develop body composition ranges, which could be used as a guide for professionals when developing individualised body composition goals for AF athletes.

7.2.4. The validation of dietary assessment tools for use with team sport athletes

Lastly, whilst this research has provided an insight into the DIs of AF athletes, it has also identified limitations associated with using dietary assessment methods such as food records and 24 hr-recalls (1, 2, 12). In particular, Chapters Four and Five identified limitations such as underreporting and reductions in the quality of food records recorded over seven days, when using self-reported food records (i.e. three and seven days) (1, 2). DI research can highlight areas for potential intervention which is useful for both practice and research. Therefore to provide an accurate picture of an athlete's habitual intake and to additionally identify those not meeting nutrition goals, future research is required to explore the development of an updated dietary assessment tool that can be used to accurately assess nutrition periodisation (33). Due to the time constraints found within professional sport, dietary assessment tools need to be time effective and place minimal burden on athletes and teams. Recently, a pilot study by Capling et al. (2019) explored the development of an athlete diet index (ADI) that aimed to provide a practical way for sports nutrition professionals to assess DIs of individual athletes and teams (33). This research identified that a technology-based assessment tools such as the ADI, could provide professionals with a rapid assessment of athletes' DIs, however authors noted that validation of the ADI is still required (33). Therefore, future research should explore the validation of dietary assessment tools such as the ADI and assess use within Australian athlete cohorts such as AF (33).

7.2.5. Conclusion

Using practice based and applied research, this PhD project aimed to provide an assessment of the NK and DIs of professional AF athletes from one professional AF club to identify gaps requiring nutrition intervention and to explore factors influencing male AF athletes' dietary behaviours and food choices. It revealed that AF athletes did not meet nutritional recommendations, particularly for energy and CHO, and had 'poor' (males) and 'average' (females) NK. Qualitative interviews revealed that male AF athletes' food choice is complex and can be influenced by a range of individual factors. Younger athletes may benefit from nutrition education related to performance with less focus on body composition goals. Future research should explore time-effective nutrition education strategies that promote an individualised approach. It was identified that athletes preferred one-on-one, individualised advice from sports nutrition professionals in comparison to group education strategies such as cooking programs. Taken together, this research provides a valuable insight into the current gaps requiring nutrition intervention in professional AF and identifies the importance of an individualised approach to ensure DIs meet training and competition demands. Lastly, this research presents a strong case for the importance of embedding a sports nutrition professional into the team sport environment, to ensure dietary advice provided to athletes is aligned with overall performance goals.

7.3. Application of Research into Practice

As discussed in Chapter One, this PhD was undertaken as part of an industry-based partnership, whereby my role was embedded within one professional AF club, where I conducted research in conjunction with practicing as team sports dietitian. This opportunity allowed me to work as a part of the multi-disciplinary team and provide athletes with dietary advice that was aligned with their overall performance goals. I was able to build rapport with staff and athletes over several years which promoted mutual respect and as a result increased support towards the nutrition program.

Table 22. Improvements made to AF nutrition program as a result of research

	Improvements to AFL nutrition program
Dietitian position (AFL)	Research identified that professional male AF athletes want and require greater access to individualised nutrition advice (2). As a part of the PhD project, the research was translated into practice and resulted in a nutrition professional being seen as an essential role within the multi-disciplinary team. Post completion of the PhD project, the team sports dietitian role was increased from a previous allocation of 6 hours per week, to 25 hrs per week, which is an increase of approximately 400%. Furthermore, nutrition was recognised as an 'essential service' and even included in skeleton staff kept on to support male AF athletes during the Covid-19 pandemic state of emergency and within the 'AFL isolation hub'.
Dietitian position (AFLW)	Research identified, that professional female AF athletes did not meet energy, CHO, calcium and iron recommendations and had 'average' NK (1, 14). As a part of the industry-based partnership, the sports dietitian and head researcher serviced both the mens' squad (AFL) and womens' squads (AFLW).

	Findings highlighted in Chapters Four and Five identified the need for greater access to tailored nutrition advice and education to support these athletes to meet goals related to their training and competition. As a result, in 2018, greater funding was allocated into a separate sports dietitian role, to provide greater access to service within the AFLW program.
Improved access to food items (AFL squad)	Research identified that many AF athletes did not meet energy and CHO goals, particularly on main training days. At the time of commencement of research, athletes had limited access to food-related services such as in-house catering, team kitchen and recovery snacks. Research presented in Chapters Four and Five provided evidence to support the need for greater access to meals and snacks, particularly on main training days to support athletes to meet their nutrition goals. As a result, in 2019 greater funding was allocated towards the team meal environment with funding used to: - Create a team kitchen to be used by all AF club athletes (i.e. AFL and AFLW) and staff. - The provision of in-house catering (i.e. external catering company), on main training days. - Increased availability of ready to eat training foods on main training days (i.e. breakfast options, pre and post training snacks). - Additional funding provided to supply foods for travel to optimise preparation for game days (i.e. travel foods for plane and post-game meals)

As a direct outcome of this research, increased funding was allocated towards access to individualised nutrition advice for athletes, with the sports dietitian position funding increasing from 6 hours to 25 hours per week (i.e. 400% increase). The success of this project came down to the translation of knowledge into practice and the obvious performance outcomes observed by the leadership of the club.

New knowledge gained from this PhD research was translated into practical strategies to improve the delivery of nutrition interventions and related services within the AF club (detailed in Table 22), including:

- The development of practical CHO periodisation strategies, to improve CHO intakes surrounding main training days and competition.
- The introduction of catering on main training days to help support athletes in meeting their energy and CHO needs.
- The inclusion of experienced athletes in nutrition messages and education to support younger, inexperienced athletes meeting their nutrition goals
- The use of technology (i.e. TV screens) to provide sport specific nutrition information, to support improvements in NK.

References

1. Jenner S, Devlin B, Forsyth A, Belski R. Dietary intakes of professional Australian football league women's (AFLW) athletes during a preseason training week. Journal of Science and Medicine in Sport. 2019;22(11):1266-1271.
2. Jenner S, Trakman G, Coutts A, Kempton T, Ryan S, Forsyth A, Belski R. Dietary intake of professional Australian football athletes surrounding body composition assessment. Journal of the International Society of Sports Nutrition. 2018;15(1).
3. Kerksick C, Wilborn C, Roberts M, Smith-Ryan A, Kleiner S, Jäger R, Collins R, Cooke M, Davis J, Galvan E, Greenwood M, Lowery L, Wildman R, Antonio J, Kreider R. ISSN exercise & sports nutrition review update: research & recommendations. Journal of the International Society of Sports Nutrition. 2018;15(1):38.
4. Johnston R, Black G, Harrison P, Murray N, Austin D. Applied Sport Science of Australian Football: A Systematic Review. Sports Medicine. 2018;48(7):1673-1694.
5. Jeukendrup A. Periodized Nutrition for Athletes. Sports Medicine. 2017;47(1):51-63.
6. Impey S, Hearris M, Hammond K, Bartlett J, Louis J, Close G, Morton J. Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis. Sports Medicine. 2018;48(5):1031-1048.
7. Gamble P. Periodization of Training for Team Sports Athletes. Strength & Conditioning Journal. 2006;28.
8. Burke L. Practical sports nutrition: Champaign, Ill. : Human Kinetics; 2007.
9. Coutts A., Quinn J., Hocking J., Castagna C, Rampinini, E. Match running performance in elite Australian rules football. Journal of Science and Medicine in Sport. 2009;13(5):543-548.
10. Burke L, Hawley J, Jeukendrup A, Morton J, Stellingwerff T, Maughan R. Toward a Common Understanding of Diet–Exercise Strategies to Manipulate Fuel Availability for Training and Competition Preparation in Endurance Sport. International Journal of Sport Nutrition and Exercise Metabolism. 2018;28(5):451-463.

11. Lane S, Camera D, Lassiter D, Areta J, Bird S, Yeo WK, Jeacocke N, Krook A, Zierath J, Burke L, Hawley J. Effects of sleeping with reduced carbohydrate availability on acute training responses. Journal of Applied Physiology. 2015;119:jap.00857.2014.
12. Jenner S, Buckley G, Belski R, Devlin B, Forsyth A. Dietary Intakes of Professional and Semi-Professional Team Sport Athletes Do Not Meet Sport Nutrition Recommendations—A Systematic Literature Review. Nutrients. 2019;11(5):1160.
13. Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, Meyer N, Sherman R, Steffen K, Budgett R, Ljungqvist A. The IOC consensus statement: beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). British Journal of Sports Medicine. 2014;48(7):491-497.
14. Jenner S, Devlin B, Forsyth A, Belski R. Assessing the nutrition knowledge of professional female Australian football (AFLW) athletes. Journal of Science and Medicine in Football. 2020:1-6.
15. Trakman G, Forsyth A, Devlin B, Belski R. A Systematic Review of Athletes' and Coaches' Nutrition Knowledge and Reflections on the Quality of Current Nutrition Knowledge Measures. Nutrients. 2016;8(9):570.
16. Trakman G, Forsyth A, Hoye R, Belski R. The nutrition for sport knowledge questionnaire (NSKQ): Development and validation using classical test theory and Rasch analysis. Journal of the International Society of Sports Nutrition. 2017;14(1).
17. Faries M. Why We Don't "Just Do It": Understanding the Intention-Behavior Gap in Lifestyle Medicine. American Journal of Lifestyle and Medicine. 2016;10(5):9-322.
18. Valliant M, Emplaincourt H, Wenzel R, Garner B. Nutrition Education by a Registered Dietitian Improves Dietary Intake and Nutrition Knowledge of a NCAA Female Volleyball Team. Nutrients. 2012;4(6):506-516.
19. Tam R, Beck K, Manore M, Gifford J, Flood V, O'Connor H. Effectiveness of Education Interventions Designed to Improve Nutrition Knowledge in Athletes: A Systematic Review. Sports Medicine. 2019;49(11):1786-1796.
20. Franko D, Cousineau T, Trant M, Green T, Rancourt D, Thompson D, Ainscough J, Mintz L, Ciccazzo M. Motivation, self-efficacy, physical activity and nutrition in college students:

Randomized controlled trial of an internet-based education program. Preventive Medicine. 2008;47(4):369-377.

21. Karpinski C, Touger-Decker R, Denmark R, Rigassio-Radler D, Rosenbloom C. Impact of a Nine-Week Interactive Internet-Based Nutrition Education Program on Nutrition Knowledge and Dietary Behaviors of Collegiate Athletes. Journal of the Academy of Nutrition and Dietetics. 2012;112(9):15.
22. Simpson A, Gemming L, Baker D, Braakhuis A. Do Image-Assisted Mobile Applications Improve Dietary Habits, Knowledge, and Behaviours in Elite Athletes? A Pilot Study. Sports. 2017;5(60).
23. Birkenhead K, Slater G. A Review of Factors Influencing Athletes' Food Choices. Sports Medicine. 2015;45(11):1511-1522.
24. Ono M, Kennedy E, Reeves S, Cronin L. Nutrition and culture in professional football. A mixed method approach. Appetite. 2012;58(1):98-104.
25. Jenner S, Devlin B, Forsyth A, Belski R. Dietary intakes of professional Australian football league women's (AFLW) athletes during a preseason training week. Journal of Science and Medicine in Sport. 2019.
26. Bilsborough J, Kempton T, Greenway K, Cordy J, Coutts AJ. Longitudinal changes and seasonal variation in body composition in professional Australian football players. International Journal of Sports Physiology and Performance. 2017;12(1):10-7.
27. Thomas D, Erdman K, Burke L. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine and Science in Sport and Exercise. 2016;48(3):543-568.
28. Veale J, Pearce A, Buttifant D, Carlson J. Anthropometric Profiling of Elite Junior and Senior Australian Football Players. International Journal of Sports Physiology and Performance. 2010;5:509-520.
29. Devlin B, Kingsley M, Leveritt M, Belski R. Seasonal changes in soccer players' body composition and dietary intake practices. Journal of Strength and Conditioning Research. 2017;31(12):3319-3326.

30. Hencken C, White C. Anthropometric assessment of Premiership soccer players in relation to playing position. European Journal of Sport Science. 2006;6(4):205-211.
31. Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. Journal of Sport Sciences. 2000;18(9):669-683.
32. Mills C, De Ste Croix M, Cooper S. The Importance of Measuring Body Composition in Professional Football Players: A Commentary. Sports and Exercise Medicine. 2017;3:24-29.
33. Capling L, Gifford J, Beck K, Flood V, Slater G, Denyer G, O'Connor H. Development of an Athlete Diet Index for Rapid Dietary Assessment of Athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2019;29(6):1-8.

APPENDICES

APPENDIX A. A Review of Current Sports Nutrition Recommendations and Implications for Sports Nutrition Professionals

Over the past 10 years, thousands of research papers have been published in the discipline of sports nutrition including research that has assessed the DIs of athletes, measured the effectiveness of ergogenic supplements and evaluated dietary strategies to improve DIs of athletes. Growth in the area of sports nutrition practice has been highlighted by the vast increase in sports nutrition recommendation papers and consensus guidelines, with over 18 of these published in the past decade alone (1-18). In particular, the ISSN reports that in 2017 alone, over 2000 articles were published in the area of 'Sports Nutrition' (17). Sports nutrition professionals are guided by these recommendations which are advocated by governing organisations such as the IOC, ACSM and the ISSN. Given that there is strong evidence to suggest that improving nutritional practices can promote athletic performance, there is need to continually develop evidence based practice principles that help to support athletes to achieve performance related goals (1).

Recommendations have evolved considerably in recent times, with a greater focus made on an individualised approach (19). What has remained stable, is the focus on the important building blocks of good nutrition (Figure 10). Governing agencies highlight the importance of tailoring dietary plans to meet individual athlete energy and nutrient goals, as well as focus on the timing and distribution of intake over a training week (1). What is also consistent amongst recommendation papers is the opinion that ergogenic aids and supplements are classed as the 'cherry on top', with athletes only achieving benefits from these when foundations of 'Good nutrition' are achieved first (1). Greater access to nutrition information is available from a range of sources and platforms, with not all available information being accurate or up-to-date, therefore for sports nutrition professionals working in the field there is a primary responsibility to educate athletes on the foundations of good nutrition and to guide informed decisions around safe supplements use (15). Therefore, for the requirements of this PhD project it was deemed important to summarise the available research on dietary strategies that promote performance, in order to ensure research and recommendations were based on evidence-based practice. This review will aim to compare and assess current sports nutrition recommendations available for energy, macronutrients (i.e. CHO, fat, protein), micronutrients (i.e. calcium and iron) and hydration.

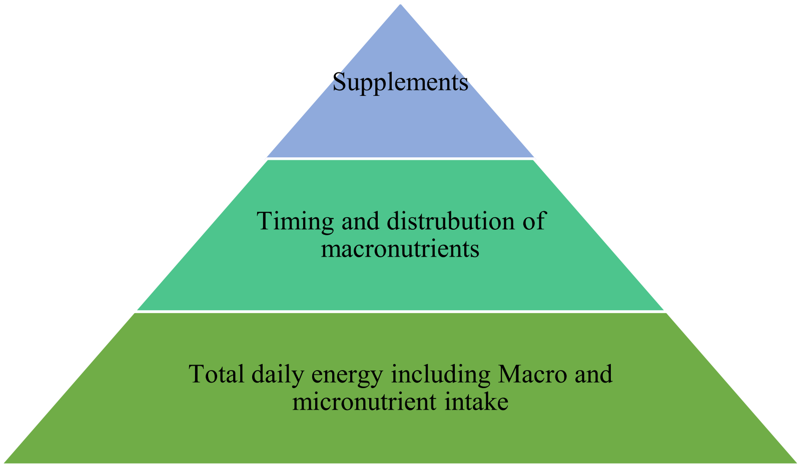

Figure 10. Building blocks of “Good nutrition” promoted by sports nutrition recommendations

8.1. Energy recommendations

When determining an athlete’s overall energy goals, it is important dietary planning is dynamic and takes into account the individual athlete goals (i.e. body composition), training and competition demands (1). Dietary planning that meets the individual athlete’s energy goals, should help to achieve optimal performance, support recovery and maintain normal bodily function (17). Energy recommendations have evolved and are used by many working in the field as a guide to determine athletes’ energy requirements (1, 12, 16, 17, 20). It is important to note that currently energy recommendations are not sport specific and therefore translating recommendations into practical advice will require an understanding of the physiological demands of different individual and team based sports (21). Therefore, an athlete’s energy outputs (i.e. training and competition demands), sport centred goals including body composition goals (i.e. maintain, alter or increase FFSTM and individual characteristics (i.e. body mass, age etc.) are important to take into consideration when estimating an athlete’s energy goals (1).

Furthermore, when translating recommendations into individual athlete needs, an understanding about the main energy systems used during physical activity is essential. To provide fuel for the working muscles during physical activity, energy systems such as the phosphagen and glycolytic (anaerobic) and

Table 23. Summary of energy recommendations from the past 10 years.

Date	Organisation	Energy Recommendations
2018	ISSN (17)	• 25-35 $kcal \cdot kg^{-1} \cdot day^{-1}$ (exercising 30-40 $mins \cdot day^{-1}$; 3 times per week) • 40-70 $kcal \cdot kg^{-1} \cdot day^{-1}$ (exercising 2-3 $hrs \cdot day^{-1}$ of intense exercise; 5-6 times per week)
2016	ACSM, IOC and ISSN (12)	• 25-25 $kcal \cdot kg^{-1} \cdot day^{-1}$ (30-40 $mins \cdot day^{-1}$; 3 times a week) • 50-80 $kcal \cdot kg^{-1} \cdot day^{-1}$ (2-3 hrs intense training; 5-6 times a week) • 1150-200 $kcal \cdot kg^{-1} \cdot day^{-1}$ (Professional Athletes) 60-80 $kcal \cdot kg^{-1} \cdot day^{-1}$ (Large athletes)
2016	American college of Sports Nutrition, ADA and Dietitians of Canada 1 (1)	• Harris benedict equation with activity Factors
2010	ISSN (16)	• 25-35 $kcal \cdot kg^{-1} \cdot day^{-1}$ (exercising 30-40 $mins \cdot day^{-1}$; 3 times per week) • 50-80 $kcal \cdot kg^{-1} \cdot day^{-1}$ (exercising 2-3 $mins \cdot day^{-1}$ of intense exercise; 5-6 times per week)
2009	American college of Sports Nutrition, ADA and Dietitians of Canada (20)	• Harris benedict equation with activity Factors

Abbreviations: ISSN; International Society of Sports Nutrition, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association.

oxidative (aerobic) pathways can be used interchangeably. A variety of variables including the type, frequency, intensity and duration of physical activity, in combination with individual factors such as substrate availability will determine the contribution of each energy system (1).

For example high-intensity power-based sports or movements, will predominately use the phosphagen system (i.e. power lifting, shot put etc.), however for events lasting longer than 2-3 minutes oxidative pathways will be used (i.e. marathon, team sports and cycling) (1, 22). Team sports which are characterised by intermittent high-intensity movements, interspersed with bouts of rest periods will use a combination of anaerobic and aerobic energy systems (23). Therefore, when estimating energy requirements, sports nutrition professionals may need to use a trial and error approach and undertaken continuous athlete monitoring to prevent a mismatch between energy expenditure and energy intake.

Negative energy balance which can occur as a result of a mismatch between energy expenditure and energy intake, if undertaken for long periods of time can increase the loss of FFSTM and bone mineral density, influence menstrual function and increase the susceptibility to injury and illness (1, 11). Recently, there has been an increased focus on the effects of inadequate energy intake or LEA on athletes' performance, recovery and overall health (i.e. <30 $kcal \cdot kg^{-1} \cdot day^{-1}$) (11). RED-S syndrome is a condition characterised by the existence of LEA and occurs as a result of energy intakes that are inadequate to support normal bodily function (10, 11). Previously, literature has reported LEA within female athlete populations and those competing in aesthetic based sports (i.e. gymnastics, dancing etc.) (10, 11). More recently, LEA has become increasingly more common in male athletic populations competing in a range of individual and team sports (11, 24). Because of this, a greater emphasis has been placed on the importance of tailoring energy intakes to match energy expenditure and identify and monitor athletes at risk (25, 26). The term 'Periodised nutrition' has been developed over time and is defined by Jeukendrup et al. (2017) as the '*the strategic combined use of exercise training and nutrition OR nutrition only, with the overall aim to obtain adaptations that support exercise performance'* (26). Athletes competing in individual and team sports have training schedules that are periodised to enhance physiological responses to training and where required support recovery processes. Therefore, to support an athlete's performance and recovery needs, DIs should be tailored according to training and competition outputs. Using this knowledge, future research into the development of sport specific recommendations, that take into consideration the energy demands of different sports, may be useful as a guide for estimating an athlete's energy requirements (27).

8.2. CHO recommendations

8.2.1. CHO Training recommendations

For sporting performance including physical activity that lasts several minutes to hours and of varying intensities (i.e. intermittent vs low intensity) CHO will be used to fuel athletes in and around training and competition (1, 19). Athletes' CHO requirements are much greater than the general public due to the need for glycogen availability which will fuel the working muscles during physical activity (1, 17). However, attention must be paid to careful dietary planning to ensure DIs match an athlete's training and competition needs and where required can be manipulated to promote physiological responses to training (28). The CHO food group which includes wholegrain breads and cereals, fruits, starchy vegetables and dairy, is not only important for the provision of glycogen to fuel sports performance but also contains a range of micronutrients required for normal growth, development and overall health (17).

Complex CHOs such as those found in wholegrain cereals, fruits and starchy-vegetables, additionally provide a source of fibre (including resistance starch) which has been linked to the maintenance and development of diversity in the gut microbiome (29). Greater microbiome diversity has been linked to increased short chain fatty acid production, antioxidant production, improved lipid metabolism and is important in reducing the risk of infection and inflammation (30, 31). In particular, a recent study by Jang et al. (2019) compared the DIs of body builders, elite distance runners and healthy males and found diets reported by athletes that were high in protein, negatively impacted their microbiome diversity (32). Furthermore, this study found high protein, lower CHO diets were associated with reduced production of short-chain fatty acid producing bacteria which can limit diversity of the gut microbiome (32, 33). It is important to note that the relationship between the gut microbiome and athletic performance is complex, with many variables to consider, including training outputs (31). This research does support the inclusion of high CHO foods in the athlete's diet for the promotion of improved gut microbiome, however it also highlights that greater research is required in this growing area. Sports nutrition recommendations historically have provided broad ranges to take into consideration the needs of a variety of individual and team sports. Table 24 provides a summary of CHO recommendations advocated by governing organisations over the past decade. Currently recommendations promote large CHO intakes, with minimal focus on a periodised approach.

Table 24. Summary of CHO recommendations advocated by sports nutrition organisations for training from the past 10 years.

Date	Organisation	CHO recommendations (training)
2018	ISSN (17)	• 3-5 $g \cdot kg^{-1} \cdot day^{-1}$ (general fitness program) • 5-8 $g \cdot kg^{-1} \cdot day^{-1}$ (2-3 h of intense exercise per day; 5-6 days a week) • 8-10 $g \cdot kg^{-1} \cdot day^{-1}$ (3-6 h of intense exercise per day; 1-2 daily workouts for 5-6 days a week)
2017	ISSN (18)	• 5-12 g-kg-day (moderate to high-intensity exercise)
2016	ACSM, IOC and ISSN (12)	**ACSM** • 6-10 $g \cdot kg^{-1} \cdot day^{-1}$ **ISSN** • 3-5 $g \cdot kg^{-1} \cdot day^{-1}$ (30-60 $mins \cdot day^{-1}$, 3-4 times a week) • 5-8 $g \cdot kg^{-1} \cdot day^{-1}$ (2-3 $hrs \cdot day^{-1}$; 5-6 times a week) • 8-10 $g \cdot kg^{-1} \cdot day^{-1}$ (3-6 $hrs \cdot day^{-1}$; 1-2 sessions, 5-6 times a week) **IOC** • 7 $g \cdot kg^{-1} \cdot day^{-1}$ (7-12 $g \cdot kg^{-1} \cdot day^{-1}$ per 24 hrs; general fuelling events up to >90 minutes.
2010	ISSN (16)	• 55-65% TEI OR 5-8 $g \cdot kg^{-1} \cdot day^{-1}$ (2-3 h of intense exercise per day; 5-6 days a week) • 8-10 $g \cdot kg^{-1} \cdot day^{-1}$ (3-6 h of intense exercise per day; 1-2 daily workouts for 5-6 days a week)
2009	American college of Sports Nutrition, ADA and Dietitians of Canada (20)	• 6-10$g \cdot kg^{-1} \cdot day^{-1}$

Abbreviations: CHO; Carbohydrate, ISSN; International Society of Sports Nutrition, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association, NA; not available, TEI; total energy intake

In particular, many team sport athletes will train with periodised training loads therefore the need for consistently high CHO intakes such as those recommended (i.e.5-10 $g \cdot kg^{-1} \cdot day^{-1}$), may not be required (34). The practicality of consuming large CHO doses irrespective of training expenditures, and thereby exceeding overall energy balance, has been questioned for athletes that need to maintain optimal body composition for their chosen sport (35). Recently, more research has explored the use of dietary manipulation strategies within endurance based athlete cohorts (28, 36). Dietary strategies such as 'Fuel for the work required' uses a model of manipulating CHO availability across a training week, to enhance mitochondrial cell signalling which plays an important role in ATP synthesis (28). However, when using dietary manipulation strategies it is important sports nutrition professionals promote CHO availability around high training loads and competition, as it has been found competing in a glycogen depleted state can limit performance with side effects such as fatigue, muscle soreness and decreased concentration observed (37).

Furthermore, CHOs have gained media attention, potentially due to an influx of various diet strategies, that aim to remove or limit CHO intake for weight loss or for the manipulation of body composition (i.e. Ketogenic diet, Low CHO High Fat (LCHF), Atkins diet etc.)) (19). In combination with pressures associated with athletes meeting body composition goals, research has identified many consume suboptimal CHO intakes (11, 38). The mechanisms behind LCHF diets suggest an athlete's exercise capacity can be upregulated by DIs that are high in fat equating to ~65-70% of total energy and low in CHO (~<2.5 $g \cdot kg^{-1} \cdot day^{-1}$) (39). It has been found that an increase in free fatty acid (FFA) oxidation which occurs as a result of muscle and liver glycogen depletion – is not sufficient enough to replace CHO as a fuel and does not appear to enhance performance or exercise capacity (39). In particular, in sports where high-intensity outputs are required such as sprinting, the up-regulation of fatty acid oxidation is not able to cover the costs of ATP-resynthesis required (34). In addition, decreasing the body's substrate pool and/or the ability to oxidize CHO, may also decrease an individual's metabolic flexibility (19). Collectively, current research and recommendations support the use of CHO (i.e. glycogen) as a major fuel source for activity. Taken together, there is greater support for a 'Periodised approach' when it comes to providing nutrition advice, whereby CHO intakes are tailored in and around high training loads and competition (19, 28, 36). By manipulating the availability of fuel sources according to training loads, research has been able to show improvements in metabolic flexibility and an increase in the body's capacity to switch interchangeably between fuel sources (i.e. CHO and fat) (19). Research into the efficacy of LCHF diets on athletic performance is still evolving, and therefore it is important as sports nutrition professionals that a 'one-size fits all' approach is avoided and that a range of strategies are considered when supporting athletes to reach their optimal performance goals.

8.2.2. CHO competition recommendations (pre fuelling and recovery strategies)

Further consideration is to be made when determining an athlete's CHO needs for competition and recovery. Factors including the duration of activity, type of CHO (i.e. glucose and sucrose, fructose and maltodextrin) and an athlete's tolerance to feeding (i.e. GIT function) should be included in decision making, when planning DI in and around competition (17). In particular the need for high CHO availability and feeding during exercise, will be determined by the demands of competition including the duration (17). To achieve an ergogenic outcome from CHO feeding during exercise, research highlights that physical activity needs to extend beyond 90 minutes (17). Recommendations suggest that for exercise between 30-75 minutes, small amounts of CHO are required during activity either in the form of mouth rinses or small CHO feedings (40). For events lasting approximately two to three hours, CHO feeding may be required at a rate of 30-60 $g \cdot hr^{-1}$ and for activity greater than three hours needs can exceed 90 $g \cdot hr^{-1}$, to maintain muscle glycogen levels (37). More aggressive CHO fuelling during activity is recommended for exercise the extends beyond two to three hours (37).

The type of CHO provided to athletes during physical activity needs to be trialled, as the oxidation rates of different types of CHO will differ (i.e. glucose, fructose and sucrose) (17, 40). In particular, as a result of the sodium-dependent transport required for intestinal CHO uptake, research has identified that the exogenous oxidation of a single CHO source has an upper limit of 60 $g \cdot hr^{-1}$ (40). The main purpose of CHO feeding during activity is to delay fatigue and to improve performance, therefore for events where CHO feeding is required, it is recommended that multiple transportable CHO are used (40). For example, during activity the co-ingestion of maltodextrin and fructose at a rate of 1-1.2 to 0.8-1.0, has been found to yield the greatest rates of CHO oxidation (17). However, just as important as dietary just as important as dietary planning around CHO feeding it is integral that athletes prioritise time before competition to trial plans and undertake nutrition training (i.e. training the gut) to prevent the incidence of GIT distress (40).

Table 25. Summary of CHO competition recommendations advocated by sports nutrition organisations for training from the past 10 years.

Date	Organisation	CHO recommendations	
		For competition	**For recovery**
2018	ISSN (17)	• 1.1 $g \cdot min^{-1}$ OR about 60 $g \cdot hr^{-1}$ (for exercise that lasts 2-3 hrs)	
2017	ISSN (18)	• ~30-60 $g \cdot hr^{-1}$, in a 6-8% CHO-electrolyte solution, every 10-15 minutes throughout exercise bout (for exercise >60 minutes).	• 1.2 $g \cdot kg^{-1} \cdot hr^{-1}$ for 4-6 h post exhausting exercise to stimulate muscle glycogen (4hr recovery time)
2016	ACSM, IOC and ISSN (12)	**ACSM** • 200-300 g, 3-4 hrs prior (pre-event meal) aim for 0.7 $g \cdot kg^{-1} \cdot day^{-1}$ **OR** 30-60 $g \cdot hr^{-1}$ (during exercise >60 minutes) **ISSN** • 8-10 $g \cdot kg^{-1} \cdot day^{-1}$ (1-3 days prior) **IOC** • 7-12 $g \cdot kg^{-1} \cdot day^{-1}$ (7-12 $g \cdot kg^{-1} \cdot day^{-1}$ per 24 hrs for general fuelling (i.e. events up to >90 minutes).	**ACSM** • 1.0-1.5 $g \cdot kg^{-1} \cdot day^{-1}$ (during first 30 minutes and again every 2 hrs for 4-6 hrs) **ISSN** • 1.5 $g \cdot kg^{-1} \cdot day^{-1}$or 0.6-1.0 $g \cdot kg^{-1} \cdot day^{-1}$ (during first 30 minutes, and again every 4-6 hrs) **IOC** • 1-1.2 $g \cdot kg^{-1} \cdot day^{-1}$ (first 4 hours, then resume daily fuel needs)
2010	ISSN (16)	• 1 g of CHO per minute **OR** 60 gram per hr (~30-70 $g \cdot hr^{-1}$ for 50-100 kg individual)	• 1 $g \cdot hr^{-1}$ of CHO (following intense exercise)
2009	American college of Sports Nutrition, ADA and Dietitians of Canada (20)	• ~30-60 $g \cdot hr^{-1}$	• ~1.0-1.5 $g \cdot kg^{-1}$ of body mass during the first 30 minutes and again every 2hr for 4-6 hr.

Abbreviations; Abbreviations: ISSN; International Society of Sports Nutrition, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association, CHO; carbohydrate, NA; not available, TEI; total energy intake.

In addition, it is important that dietary planning focuses on an athlete's recovery nutrition, especially for sports where repeat bouts of performance are required (i.e. batting or court sports) or when athletes have a limited recovery window (25). Most nutrition strategies centre around the co-ingestion of protein and CHO, to accelerate glycogen resynthesis and to enhance muscle protein resynthesis. To enhance glycogen resynthesis, recommendations advise for the consumption of CHO dense foods directly post physical activity and a larger high CHO meal within two-hours (Table 25) (17). Recovery meals should be suited to individual athletes' preferences including taste and tolerance post activity, with research highlighting that the form in which CHO is provided to athletes (i.e. liquid vs solid), will have no influence on recovery rates (25).

8.3. Protein recommendations

For athletes, a diet that includes adequate protein is particularly important for the building and development of FFSTM, restructuring of tendons and bone and is additionally important for optimising recovery post-exercise (1, 14). Due to the strong links found between FFSTM and a variety of performance attributes including strength, power and agility, it is understood why recommendations advocate for adequate consumption to prevent side effects related to negative protein balance (i.e. muscle wasting, injury and illness) (17). More recently, research has identified the benefits of dietary strategies focussed on protein intake, for the manipulation of BF which have also appeared to simultaneously prevent losses of FFSTM (58, 59). To promote gains in FFSTM, the timing of protein intake is particularly important and when combined with an exercise stimulus such as resistance-based exercise, muscle protein synthesis (MPS) can be enhanced (58, 59).

The type, quality and dose of protein recommended to athletes will be determined on an individual needs basis. Variables such as the type of training and experience level, as well as nutrient needs (i.e. CHO and total energy availability) will need to be considered (1). Sports nutrition recommendations advocate for protein intakes that range between 1.4-2.0 g of protein, per kg of body mass per day ($g \cdot kg^{-1} \cdot day^{-1}$) and depending on an athlete's needs higher protein intakes may be recommended (i.e. 2.3-3.1 $g \cdot kg^{-1} \cdot day^{-1}$). For example high protein intakes (i.e. > 3.0 $g \cdot kg^{-1} \cdot day^{-1}$) maybe recommended for resistance trained athletes when there is a need to reduce FFSTM loss during hypocaloric periods (1). Evidence also suggests protein intakes that exceed 2.4 $g \cdot kg^{-1} \cdot day^{-1}$, may be beneficial for athletes where the manipulation of body composition is required (i.e. to promote BF loss) (17, 41).

8.3.1. Protein quality and type

The quality of a protein food is determined by the concentration and profile of amino acids and bioavailability. EAAs can only be obtained from an individual's diet, due to the bodies inability to synthesise them naturally (1). EAAs play a key role in muscle protein synthesis (MPS) and are important for normal bodily function (1). Furthermore, branched chain amino acids (BCAA) such as Leucine are essential to stimulate muscle protein related machinery and will maximise rates of MPS (1). High quality protein sources, are those that contain higher amounts of Leucine and available EAAs and are predominately found in animal based sources such as meat, poultry, eggs, seafood and dairy (42). In comparison to plant based protein sources, animal based proteins such as whey protein hydrolysate have higher concentrations of EAAs and leucine relative to serving size and as a result have been shown to result in greater rates of MPS and muscle hypertrophy (42). Furthermore. animal and dairy based proteins are seen as a superior protein choice due to their digestibility, with whey protein hydrolysate in particular found to be rapidly absorbed and digested in the GIT (42, 43). In comparison casein which is a dairy based protein has a high concentration of EAAs, however is slowly digested by the GIT (50, 51). Therefore, for circumstances where a rapid source of Leucine is required such as post activity whey protein may be preferred, in comparison when there is a need for a slow release protein such as to offset total body protein turnover (i.e. during an overnight fast) casein may be used (17).

With a growing interest and greater numbers of athletes adhering to a plant based diet, a greater focus on quantity and quality of protein, as well as the variety of protein based foods consumed is important to ensure athletes meet protein requirements (1, 44). Research undertaken utilising soy protein supplements (i.e. soy isolate) has demonstrated it to be one of the most effective plant based protein sources to enhance MPS (45). Recently, a variety of plant based protein supplements have been made available to support athletes to meet protein requirements (i.e. soy, rice, blended products), however research into the efficacy of use is limited (44). It is important to note that meeting protein requirements using a plant-based diet is not impossible, however careful dietary planning is required to ensure athletes meet their goals (i.e. FFSTM gains).

Table 26. Summary of protein recommendations advocated by sports nutrition organisations over the past 10 years.

Date	**Organisation**	**Protein recommendations**	
		Building and maintaining lean muscle	Lean muscle retention (during hypocaloric periods)
2018	ISSN (17)	• 1.4-2.0 $g \cdot kg^{-1} \cdot day^{-1}$	• 2.3-3.1 $g \cdot kg^{-1} \cdot day^{-1}$
2017	ISSN (18)	• 1.4-2.0 $g \cdot kg^{-1} \cdot day^{-1}$(20-40 OR 0.25-0.40 $g \cdot kg^{-1}$ protein doses)	
2017	ISSN (15)	• 1.4-2.0 $g \cdot kg^{-1} \cdot day^{-1}$	• 2.3-3.1 $g \cdot kg^{-1} \cdot day^{-1}$
2016	ACSM, IOC and ISSN (12)	**ACSM** • 1.2-1.7 $g \cdot kg^{-1} \cdot day^{-1}$ **ISSN** • 0.8-1.0 $g \cdot kg^{-1} \cdot day^{-1}$ (General fitness) • 1.0-1.2 $g \cdot kg^{-1} \cdot day^{-1}$ (Older individuals) • 1.0-1.5 $g \cdot kg^{-1} \cdot day^{-1}$ (Moderate amount of intense training) • 1.5-2.0 $g \cdot kg^{-1} \cdot day^{-1}$(High volume of intense training) **IOC** • 1.2-2.0 $g \cdot kg^{-1} \cdot day^{-1}$	
2010	ISSN (16)	• 1.4-2.0 $g \cdot kg^{-1} \cdot day^{-1}$	
2009	ACSN, ADA and Dietitians of Canada (20)	• 1.2-1.7 $g \cdot kg^{-1} \cdot day^{-1}$	

Abbreviations; Abbreviations: ISSN; International Society of Sports Nutrition, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association, NA; not available.

8.3.2. Optimal protein dose

Dietary strategies that promote optimal dosage, as well as consider the timing and distribution of intake over the day, will help to optimise MPS (18). To stimulate and enhance net gains in FFSTM, sports nutrition recommendations suggest an absolute dose of 20-40 g (0.2-0.55 $g \cdot kg^{-1}$) of protein, to be distributed evenly over the day (i.e. every 3-4 hours) (17). An absolute dose of 20-40 g equates to 100-120 g lean meat (including red meat, poultry, fish), 2-3 eggs, 450-500 mL milk, 200 g of Greek yoghurt or a 30 g scoop of whey protein (14, 17). Research highlights the importance of using practical judgement when determining an athlete's 'ideal absolute dose' (46). In particular, when determining an athlete's absolute protein dose, an athlete's training status and physique goals (i.e. to build FFSTM), will be important variables to consider (14). Evidence suggest that larger protein doses closer to 40 g, may be required for individuals performing whole-body resistance training for weight loss and for athletes aiming to maximise the anabolic effects of protein (i.e. enhance FFSTM gains) (46). In comparison, research has identified that for younger athletic populations, a 20 g protein dose consumed directly after resistance training, is sufficient to stimulate MPS (47). Collectively, recommendations promote the consumption of protein doses directly post-exercise to maximise recovery and strength goals (1).

8.4. Fat recommendations

For athletes, consuming a diet that contains adequate fat, can support immune function and the maintenance of intramuscular triglyceride stores which can be used as a secondary fuel during activity (17). Generally, athletes will have greater fat requirements in comparison to the general public, however requirements will be relative to an athlete's energy costs (Table 27). Sports nutrition recommendations advise fat intakes of approximately 20-35% of total energy (TE) (17). However, when there is a requirement for the manipulation of BF, modest fat intakes have been promoted (i.e. 0.5-1.0 $g \cdot kg^{-1} \cdot day^{-1}$) (17). Furthermore, greater research has been undertaken to assess the influence of different types of fat on performance and recovery outcomes (48-50). In particular, research has investigated the anti-inflammatory benefits of Omega 3 fats, which have been shown to improve recovery outcomes by reducing oxidative stress and muscle soreness post-exercise (48-50). Positive links between omega 3 fat intake and the prevention and treatment of exercise induced muscle damage and inflammation have also been identified by research (17, 22, 48). Omega 3-fatty acids (i.e. docosahexaenoic acid and eicosapentaenoic aid) are found in a variety of foods, but most predominantly in marine sources such as fatty fish and fish oils (17, 22, 48). Currently the optimal dosage of omega 3 required for athletic populations is unknown, however to achieve benefits related to good health – population recommendations suggest that a dose of 3000-5000 mg dose of omega 3, is sufficient (17).

Table 27. Summary of fat recommendations advocated by sports nutrition organisations from the past 10 years.

Date	Organisation	Fat recommendations
2018	ISSN (17)	• 30% TE (for those wanting to reduce BF 0.5-1 $g \cdot kg^{-1} \cdot day^{-1}$)
2016	ACSM, IOC and ISSN (12)	**ACSM** • 20-35% TE **ISSN** • 30 % TE **IOC** • 15-20%
2010	International Society of Sports Nutrition (16)	• 30% TE (up to 50% of TE can be safely ingested during regular high volume training)
2009	American college of Sports Nutrition, ADA and Dietitians of Canada (20)	• 20-35% TE (<20% of TE from fat does not benefit performance)

Abbreviations: ISSN; International Society of Sports Nutrition, TE; Total Energy, BF; Body Fat, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association.

The use of fat as a main fuel source during activity has recently gained attention, with greater research undertaken to explore the efficacy of high fat diets on athletic performance (51). Dietary strategies such as low carb high fat (LCHF) and the ketogenic diet, recommend DI that is high in fat (i.e. ~70-80%), moderate in protein (i.e. ~20-25% TE) and low in CHO (i.e. maximum 50 $g \cdot day^{-1}$) **(Table 28)** (15, 17, 51). Evidence suggests that when glycogen is depleted, endogenous and exogenous fat stores can be mobilized to support fuel costs (51). Currently, there is greater evidence to support the use of glycogen as a main fuel source, with no improvements seen in athletic performance with athletes in a glycogen depleted state (17, 52).

Table 28. Summary of diet categories (15)

	Composition of diet	Strengths of diets	Limitations of diet
Low-energy diets (LED)	Energy targets: LED: 800-1200 kcal·day^{-1} VLED: 400-800 kcal·day^{-1} Macronutrient composition: CHO 30-80 g.day, Protein 70-100 g· day^{-1} and Fat 15 g· day^{-1}	Rapid weight loss is expected with this diet (1.0-2.5 kg·week^{-1}). These diets usually contain LE supplements that minimise OR eliminate the need for cooking or planning.	VLED have a higher risk of severe side effects and have not been shown to preferential to LED in the long term. *It should be noted that LED and VLED have limited relevance in athletic populations.*
Low fat diets (LFD)	Macronutrient composition: LFD: 25-30% fat VLFD: 10-20% fat	LFD are commonly support by governing agencies, as there are a large evidence base for the prevention of disease. This diet has flexible macronutrient targets.	VLFD have limited evidence to support effects on body composition. A major limitation of VLFD is compliance to this diet.
Low carbohydrate diets (LCD)	Macronutrient composition: CHO: 50-100g OR 40% of TEI from CHO. (i.e. 200 g CHO)	Higher protein intake, due to adjustments made to macronutrient intake (reduced CHO). Does have greater flexibility with macronutrient proportion and food choices. Does not limit foods based on fat content.	CHO allowances may falsely convey that CHO is inherently antagonistic for BF reduction.
Ketogenic diets (KD)	Macronutrient composition: Fat: 70-80% TE Protein: ~20-25% CHO:~50 g (maximum intake).	Higher protein intake, due to adjustments made to macronutrient intake (very low CHO). Protein intakes may improve satiety, may simplify diet planning and decision making regarding food choice.	Excludes whole food groups based on CHO content which are nutrient dense and disease protective. Can compromise high-intensity training outputs, with not significant benefits found when compared to non-KD with regards to changes to body composition.
High-protein diets	Macronutrient composition: Protein: >25% TEI OR 1.2-1.6 g·kg^{-1}·day^{-1} Super High protein diet: >3 g·kg^{-1}·day^{-1}	Hight protein diets have shown benefits for improving body composition, with combined with training. Super Hight protein diets have emerging evidence base for trained subjects and may be useful to preserve lean muscle for those undergoing progressive resistance training.	High protein intakes can displace the intake of other macronutrients required for athletic performance (i.e. CHO). Additionally, without monitoring can cause spontaneous reductions in energy intake which may be contrary to the goal of weight gain.
Intermittent fasting (IF)	Alternate day fasting (ADF); 24 hrs fast, 24hr feed. Whole day fasting (WDF): 1-2 complete days of fasting per week. Time-restricted feeding (TRF): 16-20 hr fast, 4-8 hr feed.	With regards to improving body composition; ADF, WDF and TRF have strong evidence base for performing as good or better than daily caloric restriction. TRF in particular when combined with training has been found to increase fat loss, whilst maintaining strength.	There are questions if IF could be preferential to evenly distributed intakes for maximising muscle hypertrophy and strength. Caution is warranted as careful planning is required to ensure DI supports optimal performance.

This table was adapted from the ISSN 2017 position statement 'Diets and Body composition'
Abbreviations: CHO; carbohydrate, BF; Body Fat, NA; not available, TEI; total energy intake, DI; Dietary intake

In addition, high fat diets may actually compromise performance especially during events where high work rates are observed and glycogen resynthesis is required (i.e. high-intensity, short duration events) (51). Therefore, to promote performance advantages and an athlete's metabolic flexibility, research has been increasingly in support of a periodised approach to fuel availability (19). Dietary manipulation strategies such as 'Fuel for the work required' and 'Train low, Compete high' highlight that in certain scenarios the manipulation of CHO availability may be useful to promote training

8.5. Hydration recommendations

To support thermoregulation during activity and to prevent metabolic strain, hydration strategies that monitor and optimise fluid losses are essential (53). Characteristics such as body size, gender, type and duration of activity performed, will help to determine an athlete's hydration requirements and can be used to approximate fluid losses (17). Furthermore, the climate, type of activity and duration of event will influence the focus of hydration strategies, for example with higher temperatures observed during competition, strategies may focus on monitoring body temperatures (i.e. ice slurries) and fluid loss (i.e. fluid and electrolyte replacement) to manage the effects of heat stress (54). Research has found on average, athletes record fluid losses of up to 0.5-2.0 $L \cdot hr^{-1}$ during training and competition (17, 53). Inadequately replaced fluid loss has been linked to cardiovascular strain, increased core body temperature and impaired GIT function (17). Side effects associated with an approximate loss of 2% in body mass (BW) include impaired performance and cognitive function, and with greater losses (i.e. >4% BW) nausea and illness are often observed (17). Therefore, to manage fluid losses and to optimise hydration strategies, recommendations suggest athletes should consume approximately 12-16 fluid ounces (~350-500 mL) every 5-15 minutes during physical activity, either in the form of sports drink or water (17).

Table 29. Summary of hydration recommendations advocated by sports nutrition organisations from the past 10 years.

Date	Organisation	Hydration recommendations		
		Pre exercise	During Exercise	Post-exercise
2018	ISSN (17)		• 0.5-2 $L \cdot hr^{-1}$ (frequent every 5-15 mins ingestion of 12-16 fluid ounces)	
2017	**ISSN**		• For exercise >60 minutes (high-intensity) fluid regulation should consist of the consumption of 6-8% CHO-electrolyte solution; 6-12 fluid ounces, every 10-15 minutes.	
2016	ACSN, ADA and Dietitians of Canada	**ACSM** • Hydration to be initiated several hours before exercise to ensure fluid absorption and normal urine function. Aim to consume beverages and sodium food sources to increase thirst and retain fluids.	**ACSM** • Prevent >2% body mass during exercise. Fluids should contain a source of CHO and electrolytes to maintain fluid balance. **IOC** • To prevent hypohydration; fluids should be ingested at a rate of 0.5-2 $L \cdot hr^{-1}$, with frequent ingestion every 5-20 minutes of 150-20mL of fluid.	**ACSM** • If rapid recovery is required; ingest 1.5 L of fluid per kg body mass lost during exercise.
2010	ISSN (16)		• 0.5-2 $L \cdot hr^{-1}$ (frequent every 5-15 mins ingestion of 12-16 fluid ounces)	
2009	American College of Sports Nutrition, ADA and Dietitians of Canada (20)	• 4 hrs prior to exercise; 5-7 $mL \cdot kg^{-1}$ of body mass of fluid.		• Where rapid recovery required; 16-24 oz (450-675 mL) of fluid for every pound of body mass lost during exercise.

Abbreviations: ISSN; International Society of Sports Nutrition, ACSM; American College of Sports Medicine, IOC; International Olympic Committee, ADA; American Dietetic Association.

It is important that hydration planning is not limited to replacing fluids, but also considers the replacement of electrolytes such as sodium, potassium and magnesium (55). Electrolytes are readily lost in sweat during exercise and play a major role in normal bodily function. Taken together, optimal fluid and electrolyte replacement such as sodium, can maintain total body water which has been shown to decrease performance impairments during activity (55). Incorporating osmotically active solutions such as ORS within athletes' hydration plans in preparation for competition can additionally improve fluid retention (54). Therefore when determining hydration strategies, it is important that sports nutrition professionals consider a range of variables as well as individual needs of the athletes, to promote athletic performance (53).

8 6. Conclusion

There is an abundance of research available in the area of sports nutrition and therefore sports nutrition professionals have a responsibility to use an evidence-based approach when providing dietary advice. No two sports are the same, and no two athletes are the same, therefore it is important that dietary advice is tailored according to training and competition needs. Evidence suggests that dietary manipulation strategies such as 'Fuel for the work required' whereby DI is tailored according to training outputs, may be suitable to use in both individual and team based sports, to promote training adaptations and performance outcomes. Taken together, it is integral that a 'one size fits all' approach is avoided, and that dietary advice provided to athletes considers their goals to achieve overall performance and recovery goals.

References

1. Thomas D, Erdman K, Burke L. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine and Science in Sports and Exercise. 2016;48(3):543-668.
2. Desbrow B, McCormack J, Burke L, Cox G, Fallon K, Hislop M, Logan R, Marino N, Sawyer S, Shaw G, Star A, Vidgen H, Leveritt M. Sports Dietitians Australia position statement: sports nutrition for the adolescent athlete. International Journal of Sport Nutrition and Exercise Metabolism. 2014;24(5):570-584.
3. Tiller N, Roberts J, Beasley L, Chapman S, Pinto J, Smith L, Wiffin M, Russell M, Sparks S, Duckworth L, O'Hara J, Sutton L, Antonio J, Willoughby D, Tarpey M, Smith-Ryan A, Ormsbee M, Astorino T, Kreider R, McGinnis G, Stout J, Smith J, Arent S, Campbell B, Bannock L. International Society of Sports Nutrition Position Stand: nutritional considerations for single-stage ultra-marathon training and racing. Journal of the International Society of Sports Nutrition. 2019;16(1):50.
4. Jäger R, Mohr A, Carpenter K, Kerksick C, Purpura M, Moussa A, Townsend J, Lamprecht M, West N, Black K, Gleeson M, Pyne D, Wells S, Arent S, Smith-Ryan A, Kreider R, Campbell B, Bannock L, Scheiman J, Wissent C, Pane M, Kalman D, Pugh J, ter Haar J, Antonio J. International Society of Sports Nutrition Position Stand: Probiotics. Journal of the International Society of Sports Nutrition. 2019;16(1):62.
5. La Bounty P, Campbell B, Wilson J, Galvan E, Berardi J, Kleiner S, Kreider R, Stout J, Ziegenfuss T, Spano M, Smith A, Antonio J. International Society of Sports Nutrition position stand: meal frequency. Journal of the International Society of Sports Nutrition. 2011;8(1):4.
6. Goldstein E, Ziegenfuss T, Kalman D, Kreider R, Campbell B, Wilborn C, Taylor L, Willoughby D, Stout J, Graves B, Wildman R, Ivy J, Spano M, Smith A, Antonio J. International society of sports nutrition position stand: caffeine and performance. Journal of the International Society of Sports Nutrition. 2010;7(1):5.

7. Bergeron M, Bahr R, Bärtsch P, Bourdon L, Calbet J, Carlsen K, Castagna O, González-Alonso J, Lundby C, Maughan R, Millet G, Mountjoy M, Racinais S, Rasmussen P, Subudhi A, Young A, Soligard T, Engebretsen L. International Olympic Committee consensus statement on thermoregulatory and altitude challenges for high-level athletes. British Journal of Sports Medicine. 2012;46(11):770.
8. Trexler E, Smith-Ryan A, Stout J, Hoffman J, Wilborn C, Sale C, Kreider R, Jager R, Earnest C, Bannock L, Campbell B, Kalman D, Ziegenfuss T, Antonio J. International society of sports nutrition position stand: Beta-Alanine. Journal of the International Society of Sports Nutrition. 2015;12.
9. Maughan R, Burke L, Dvorak J, Larson-Meyer D, Peeling P, Phillips S, Rawson E, Walsh N, Garthe I, Geyer H, Meeusen R, van Loon L, Shirreffs S, Spriet L, Stuart M, Vernec A, Currell K, Ali V, Budgett R, Ljungqvist A, Mountjoy M, Pitsiladis Y, Soligard T, Erdener U, Engebretsen L. IOC consensus statement: dietary supplements and the high-performance athlete. British Journal of Sports Medicine. 2018;52(7):439-455.
10. Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, Meyer N, Sherman R, Steffen K, Budgett R, Ljungqvist A. The IOC consensus statement: beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). British Journal of Sports Medicine. 2014;48(7):491-497.
11. Mountjoy M, Sundgot-Borgen J, Burke L, Ackerman K, Blauwet C, Constantini N, Lebrun C, Lundy B, Melin A, Meyer N, Sherman R, Tenforde A, Klungland Torstveit M, Budgett R. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. British Journal of Sports Medicine. 2018;52(11):687-697.
12. Potgieter S. Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the International Society for Sports Nutrition. South African Journal of Clinical Nutrition. 2013;26(1):6-16.
13. Campbell B, Wilborn C, La Bounty P, Taylor L, Nelson M, Greenwood M, Ziegenfuss T, Lopez H, Hoffman J, Stout J, Schmitz S, Collins R, Kalman D, Antonio J, Kreider R.

International Society of Sports Nutrition position stand: energy drinks. Journal of the International Society of Sports Nutrition. 2013;10(1):1.

14. Jäger R, Kerksick C, Campbell B, Cribb P, Wells S, Skwiat T, Purpura M, Ziegenfuss T, Ferrando A, Arent S, Smith-Ryan A, Stout J, Arciero P, Ormsbee M, Taylor L, Wilborn C, Kalman D, Kreider R, Willoughby D, Hoffman J, Krzykowski J, Antonio J. International Society of Sports Nutrition Position Stand: protein and exercise. Journal of the International Society of Sports Nutrition. 2017;14(20):1-25.

15. Aragon A, Schoenfeld B, Wildman R, Kleiner S, VanDusseldorp T, Taylor L, Earnest C, Arciero P, Wilborn C, Kalman D, Stout J, Willoughby D, Campbell B, Arent S, Bannock L, Smith-Ryan A, Antonio J. International society of sports nutrition position stand: diets and body composition. Journal of the International Society of Sports Nutrition. 2017;14(1):16.

16. Kreider R, Wilborn C, Taylor L, Campbell B, Almada A, Collins R, Cooke M, Earnest C, Greenwood M, Kalman D, Kerksick C, Kleiner S, Leutholtz B, Lopez H, Lowery L, Mendel R, Smith A, Spano M, Wildman R, Willoughby D, Ziegenfuss T, Antonio J. ISSN exercise & sport nutrition review: research & recommendations. Journal of the International Society of Sports Nutrition. 2010;7(1):7.

17. Kerksick C, Wilborn C, Roberts M, Smith-Ryan A, Kleiner S, Jäger R, Collins R, Cooke M, Davis J, Galvan E, Greenwood M, Lowery L, Wildman R, Antonio J, Kreider R. ISSN exercise & sports nutrition review update: research & recommendations. Journal of the International Society of Sports Nutrition. 2018;15(1):38.

18. Kerksick C, Arent S, Schoenfeld B, Stout J, Campbell B, Wilborn C, Taylor L, Kalman D, Smith-Ryan A, Kreider R, Willoughby D, Arciero P, VanDusseldorp T, Ormsbee M, Wildman R, Greenwood M, Ziegenfuss T, Aragon A, Antonio J. International society of sports nutrition position stand: nutrient timing. Journal of the International Society of Sports Nutrition. 2017;14(1):33.

19. Burke L, Hawley J. Swifter, higher, stronger: What's on the menu? Science. 2018;362(6416): 7-781.

20. Rodriguez N, Di Marco N, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. Medicine and Science in Sports and Exercise. 2009;41(3):31-709.
21. Jenner S, Buckley G, Belski R, Devlin B, Forsyth A. Dietary intakes of professional and semi-professional team sport athletes do not meet sport nutrition recommendations—a systematic literature review. Nutrients. 2019;11(5).
22. Belski R, Forsyth A, Mantzioris E. Nutrition for sport, exercise and performance. Crows Nest, Australia: Allen & Unwin; 2019.
23. Holway F, Spriet L. Sport-specific nutrition: Practical strategies for team sports. Journal of Sports Sciences. 2011;29:25-115.
24. Sundgot-Borgen J, Meyer N, Lohman T, Ackland T, Maughan R, Stewart A, Müller W. How to minimise the health risks to athletes who compete in weight-sensitive sports review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition, Health and Performance, under the auspices of the IOC Medical Commission. British Journal of Sports Medicine. 2013;47(16):22-1021.
25. Burke L, Loucks A, Broad N. Energy and carbohydrate for training and recovery. Journal of Sports Sciences. 2006;24(7):85-675.
26. Jeukendrup A. Periodized Nutrition for Athletes. Sports Medicine. 2017;47(1):51-63.
27. Jenner S, Trakman G, Coutts A, Kempton T, Ryan S, Forsyth A, Belski R. Dietary intake of professional Australian football athletes surrounding body composition assessment. Journal of the International Society of Sports Nutrition. 2018;15(1):43.
28. Impey S, Hearris M, Hammond K, Bartlett J, Louis J, Close G, Morton J. Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis. Sports Medicine. 2018;48(5):48-1031-1048.
29. Oliphant K, Allen-Vercoe E. Macronutrient metabolism by the human gut microbiome: major fermentation by-products and their impact on host health. Microbiome. 2019;7(1):91.
30. Valdes A, Walter J, Segal E, Spector T. Role of the gut microbiota in nutrition and health. British Medicine Journal. 2018;361:2179.

31. Wosinska L, Cotter P, O'Sullivan O, Guinane C. The Potential Impact of Probiotics on the Gut Microbiome of Athletes. Nutrients. 2019;11(10):2270.
32. Jang L, Choi G, Kim S, Kim B, Lee S, Park H. The combination of sport and sport-specific diet is associated with characteristics of gut microbiota: An observational study. Journal of the International Society of Sports Nutrition. 2019;16(1).
33. Zhao C, Dong H, Zhang Y, Li Y. Discovery of potential genes contributing to the biosynthesis of short-chain fatty acids and lactate in gut microbiota from systematic investigation in E. coli. Biofilms and Microbiomes. 2019;5(1):19.
34. Williams C, Rollo I. Carbohydrate Nutrition and Team Sport Performance. Sports Medicine. 2015;45(1):13-22.
35. Bradley W, Cavanagh B, Douglas W, Donovan T, Morton J, Close G. Quantification of Training Load, Energy Intake, and Physiological Adaptations During a Rugby Preseason: A Case Study From an Elite European Rugby Union Squad. Journal of Strength and Conditioning Research. 2015;29(2):444-453.
36. Burke L, Hawley J, Jeukendrup A, Morton J, Stellingwerff T, Maughan R. Toward a Common Understanding of Diet–Exercise Strategies to Manipulate Fuel Availability for Training and Competition Preparation in Endurance Sport. International Journal of Sports Nutrition and Exercise Metabolism. 2018;28(5):451-463.
37. Burke L, Hawley J, Wong S, Jeukendrup A. Carbohydrates for training and competition. Journal of Sports Sciences. 2011;29:17-27.
38. Spendlove J, Heaney S, Gifford J, Prvan T, Denyer G, O'Connor H. Evaluation of General Nutrition Knowledge in Elite Australian Athletes. Med Sci Sports Exerc. 2011;43(5):501.
39. Burke L. Re-Examining High-Fat Diets for Sports Performance: Did We Call the 'Nail in the Coffin' Too Soon? Sports Medicine. 2015;45:33-49.
40. Jeukendrup A. A step towards personalized sports nutrition: carbohydrate intake during exercise. Sports Medicine. 2014;44:25-33.
41. Moore D. Maximizing Post-exercise Anabolism: The Case for Relative Protein Intakes. Frontiers in Nutrition. 2019;6(147).

42. Tang J, Moore D, Kujbida G, Tarnopolsky M, Phillips S. Ingestion of whey hydrolysate, casein, or soy protein isolate: effects on mixed muscle protein synthesis at rest and following resistance exercise in young men. Journal of Applied Physiolgy. 2009;107(3):987-992.
43. Wilkinson S, Tarnopolsky M, Macdonald M, Macdonald J, Armstrong D, Phillips S. Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenergetic soy-protein beverage. The American Journal of Clinical Nutrition. 2007;85(4):1031-1040.
44. Rogerson D. Vegan diets: Practical advice for athletes and exercisers. Journal of the International Society of Sports Nutrition. 2017;14(1).
45. Phillips S. The impact of protein quality on the promotion of resistance exercise-induced changes in muscle mass. Nutrition & Metabolism. 2016;13(1):64.
46. Stokes T, Hector AJ, Morton R, McGlory C, Phillips S. Recent Perspectives Regarding the Role of Dietary Protein for the Promotion of Muscle Hypertrophy with Resistance Exercise Training. Nutrients. 2018;10(2):180.
47. Moore D, Robinson M, Fry J, Tang J, Glover E, Wilkinson S, Prior T, Tarnopolsky M, Phillips S. Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. The American Journal of Clinical Nutrition. 2009;89(1):161-168.
48. Venkatraman T, Leddy T, Pendergast T. Dietary fats and immune status in athletes: clinical implications. Medicine and Science in Sports and Exercise. 2000;32:389-395.
49. Gray P, Chappell A, Jenkinson A, Thies F, Gray S. Fish oil supplementation reduces markers of oxidative stress but not muscle soreness after eccentric exercise. International Journal of Sport Nutrition and Exercise Metabolism. 2014;24(2):206-214.
50. Calder P. Mechanisms of action of (n-3) fatty acids. The Journal of nutrition. 2012;142(3):592-599.
51. Burke L, Kiens B. "Fat adaptation" for athletic performance: the nail in the coffin? In: Burke LM, editor. 2006.p 7-8.
52. Burke L, Ross M, Garvican-Lewis L, Welvaert M, Heikura I, Forbes S, Mirtschin J, Cato LE, Strobel N, Sharma A, Hawley J. Low carbohydrate, high fat diet impairs exercise economy

and negates the performance benefit from intensified training in elite race walkers. Journal of Physiology. 2017;595(9):2785-2807.

53. Magro D. Rocha Piedade S, Imhoff A, Clatworthy M, Cohen M, Espregueira-Mendes J. Nutrition and Hydration. In: Editors. The Sports Medicine Physician. Cham: Springer International Publishing; 2019. p. 85-98.

54. McCubbin A, Allanson B, Caldwell Odgers J, Cort M, Costa R, Cox G, Crawshay S, Desbrow B, Freney E, Gaskell S, Hughes D, Irwin C, Jay O, Lalor B, Ross M, Shaw G, Périard J, Burke L. Sports Dietitians Australia Position Statement: Nutrition for Exercise in Hot Environments. International Journal of Sport Nutrition and Exercise Metabolism. 2020;30(1):1-16.

55. McCubbin A, Costa R. Impact of Sodium Ingestion During Exercise on Endurance Performance: A Systematic Review. International Journal of Sports Science. 2018;8.

APPENDIX B. An assessment of Nutrition Knowledge tools (i.e. Questionnaires and surveys)

Nutrition Knowledge (NK) tool	Reference	Type and number (*n=x*) of Questions	Sections & subsections	Advantages	Disadvantages
Electronic nutrition literacy assessment tool (Enut-lit)	Franklin J, Holman C, Tam R, Gifford J, Prvan T, Stuart-Smith W, et al. Validation of the e-NutLit, an Electronic Tool to Assess Nutrition Literacy. Journal of Nutrition Education and Behavior. 2020;52(6):607-614.	Multiple choice *(n=67)*	- Identification of food groups - Interpreting Australian Dietary Guidelines - Recognizing nutrients - Identifying and interpreting food labels - Choosing healthy foods - Knowledge of diet-disease relation	- Assesses NK electronically (user friendly). - Tool includes questions to assess procedural based NK (i.e. label reading).	- Tool developed to assess general NK and is not sport specific (i.e. competition, recovery, hydration, supplements). - Validated and administered to a non-sport specific population (i.e. obese adults). - Greater internal testing required (i.e. construct validity) and will need to be assessed with a wider population sample (i.e. athletes).
Abridged Nutrition for Sport Knowledge Questionnaire (ANSKQ)	Trakman GL, Brown F, Forsyth A, Belski R. Modifications to the nutrition for sport knowledge questionnaire (NSQK) and abridged nutrition for sport knowledge questionnaire (ANSKQ). Journal of the International Society of Sports Nutrition. 2019;16(1):26.	Multiple choice, disagree/agree/not sure and effective/non effective/not sure *(n=37)*	- General Nutrition Knowledge - Sports Nutrition Knowledge	- Online and paper version available (user friendly). - Shorter questionnaire may improve completion rates. - Reliability and validity have been assessed (i.e. Rasch analysis and a test-retest method, respectively).	- Tool does not assess procedural based NK, skills and efficacy, and confidence.

Nutrition Knowledge (NK) tool	Reference	Type and number (*n*=*x*) of Questions	Sections & subsections	Advantages	Disadvantages
Nutrition for Sport Knowledge Questionnaire (NSKQ)	Trakman GL, Forsyth A, Hoye R, Belski R. The nutrition for sport knowledge questionnaire (NSKQ): Development and validation using classical test theory and Rasch analysis. Journal of the International Society of Sports Nutrition. 2017;14(1).	Multiple choice, disagree/agree/not sure and effective/non effective/not sure *(n=87)*	- Weight management - Macronutrients - Micronutrients - Sports nutrition - Supplements - Alcohol	- Online and paper version available (user friendly). - Reliability and Validity has been assessed using Rasch analysis and a test-retest method, respectively. - Beneficial to assess gaps in NK. - With the addition of researcher-based questions, this tool includes questions that assess efficacy, and confidence.	- Lengthy (may reduce completion rates). - Tool does not assess procedural based NK (i.e. label reading).
Revised General Nutrition Knowledge Questionnaire (GNKQ-R)	Kliemann N, Wardle J, Johnson F, Croker H. Reliability and validity of a revised version of the General Nutrition Knowledge Questionnaire. European Journal of Clinical Nutrition. 2016;70(10):1174-1180.	Open ended and multiple choice, including an ‘unsure option’ *(n=88).*	- Dietary recommendations - Food Groups - Healthy food choice - Diet, disease and weight associations	- Shorter questionnaire when compared to the original GNSK. - Reliability and validity have been assessed (i.e. sensitivity to change and construct validity).	- Lengthy questionnaire (may reduce completion rates). - Tool developed to assess general NK and is not sport specific (i.e. competition, recovery, hydration, supplements).

Nutrition Knowledge (NK) tool	Reference	Type and number (*n*=*x*) of Questions	Sections & subsections	Advantages	Disadvantages
Sports Nutrition Knowledge Questionnaire (SNKQ)	Zinn C, Schofield G, Wall C. Development of a psychometrically valid and reliable sports nutrition knowledge questionnaire. Journal of Science and Medicine in Sport. 2005;8(3):346-351.	Multi-choice, Agree/Disagree/Unsure, *(n=88)*	- General Nutrition Knowledge - Fluid - Weight Control - Supplement - Recovery	- Includes a mix of general and sports specific nutrition knowledge questions (including; hydration, supplements, recovery). - Validity and reliability tested using psychometric analysis. - Suitable for use with athletes and sporting groups.	- Tool does not assess procedural based NK, skills and efficacy, and confidence. - Lengthy (may reduce completion rates).
Dietary Habits and Nutrition Knowledge Questionnaire	Paugh, S. Dietary Habits and Nutritional Knowledge of College Athletes. [Master of Science]. California University of Pennsylvania, California, Pennsylvania; 2005.	Strongly agree/agree/neutral/disagree/strongly disagree *(n=29)*	- Food Habits - Nutrition knowledge	- Includes a mix of general and sports specific nutrition knowledge questions (including; macronutrient, supplements, hydration).	- Limited validation; no evidence of factor or Rasch analysis. - Tool developed to assess general NK and is not sport specific (i.e. competition, recovery, hydration, supplements).
General Nutrition Knowledge Questionnaire (GNKQ)	Parmenter K, Wardle J. Development of a general nutrition knowledge questionnaire for adults. European Journal of Clinical Nutrition. 1999;53(4):298-308.	Open ended and multiple choice *(n=126).*	- Dietary Recommendations - Food Groups	- Widely used in the literature (i.e. comparisons can be made between research studies). - Validity tested with a sample population (i.e. psychometric analysis).	- Tool developed to assess general NK and is not sport specific (i.e. competition, recovery, hydration, supplements). - Not a valid measure of NK due to the inclusion of outdated nutrition information (i.e. dietary recommendations.)

	- Lengthy (may reduce completion rates). - Paper version only; may limit access. - Tool does not assess procedural based NK, skills and efficacy, and confidence.

APPENDIX C: Participant Information and Consent Forms (Quantitative research)

EVALUATION OF NUTRITIONAL DATA, BODY COMPOSITION DATA, HEALTH DATA AND PERFORMANCE DATA ROUTINELY COLLECTED FROM ELITE ATHLETES The research is being carried out by the following researcher: **Sarah Jenner** The research is being carried out in partial fulfilment of PhD under the supervision of Adrienne Forsyth, Regina Belski and Brooke Devlin. The following researchers will be conducting the study:		
Role	**Name**	**Organisation**
Chief Investigator	Adrienne Forsyth	La Trobe University
External Investigator	Regina Belski	Adjunct La Trobe University
Investigator	Brooke Devlin	La Trobe University
Student	Sarah Jenner	La Trobe University/Carlton Football Club
Research funder	EVALUATION OF NUTRITIONAL DATA, BODY COMPOSITION DATA, HEALTH DATA AND PERFORMANCE DATA ROUTINELY COLLECTED FROM ELITE ATHLETES. This research is supported by in kind support by La Trobe University.	

1. **What is the study about?**
   You are invited to participate in a study of existing and routinely collected data on participants' current nutrition knowledge, behaviour and body composition. We hope to use this data to inform dietetic practice and in the longer term develop personalised nutrition interventions to help those athletes to achieve optimal health and performance. Participants have been selected and recruited from the playing list at Carlton Football Club as this research is focusing on elite athletes. Your contact details were obtained from team dietitian, Sarah Jenner as a part of PhD research.

2. **Do I have to participate?**
   Being part of this study is voluntary. If you want to be part of the study we ask that you read the information below carefully and ask us any questions.

   You can read the information below and decide at the end if you do not want to participate. If you decide not to participate this won't affect your relationship with La Trobe University or any other listed organisation.

3. **Who is being asked to participate?**
   You have been asked to participate due to the following inclusion criteria:
   - Elite athlete; competing in the Australian Football (AFL), Australian Football Women's (AFLW) and Victorian Leagues (VFL)
   - Aged between 13-40 years
   - Participate in full to part time training- minimum 15 hours per week.

4. **What will I be asked to do?**

If you want to take part in this study, we will ask you to consent for use of the information they provide regarding their dietary practices that is routinely collected as a part of clinical practice by the club dietitian such as dietary intake data, nutrition knowledge, body composition (i.e. Dual Energy X-ray Absorptiometry) and Global Positioning Systems (GPS).

5. What are the benefits?

The benefit of you taking part in this study is that the data collected in this study will inform dietetic practice and in the longer term, enable the development of personalised nutrition interventions to help athletes achieve optimal health and performance. The expected benefits to society in general are that the data collected may be published and if so, will help set the context for baseline nutrition knowledge and behaviour of elite athletes in Australia to support the work of coaching staff and dietitians as well as other researchers.

6. What are the risks?

With any study there are (1) risks we know about, (2) risks we don't know about, and (3) risks we don't expect. If you experience something that you aren't sure about, please contact us immediately so we can discuss the best way to manage your concerns.

Name/Organisation	Position	Telephone	Email
Sarah Jenner	Researcher	0422644593	19280002@students.ltu.edu.au

Nil risks have been associated with current research. You will not be required to do anything extra to participate in this study, only to consent to having your data collected by the club dietitian.

7. What will happen to information about me?

We will collect and store information about you in ways that will not reveal who you are. This means you cannot be identified in any type of publication from this study.

We will keep your information for 7 years after the project is completed. After this time, we will destroy all your data.

We will collect, store and destroy your data in accordance with La Trobe Universities Research Data Management Policy which can be viewed online using the following link: https://policies.latrobe.edu.au/document/view.php?id=106/.

The information you provide is personal information for the purposes of the Information Privacy Act 2000 (Vic). You and your child have the right to access personal information held about you by the University, the right to request correction and amendment of it, and the right to make a compliant about a breach of the Information Protection Principles as contained in the Information Privacy Act.

8. Will I hear about the results of the study?

We will let you know about the results of the study via the team dietitian, who will provide individual feedback as a part of routine practice.

9. What if I change my mind?

At any time, you can choose to no longer be part of the study. You can let us know by:

1. Completing the ‘Withdrawal of Consent Form’ (provided at the end of this document);
2. Calling us;
3. Emailing us

Your decision to withdraw at any point will **not** affect your relationship with La Trobe University or any other organisation listed. When you withdraw, we will stop asking you for information. Any identifiable information about you will be withdrawn from the research study. However, once the results have been analysed, we can only withdraw information, such as your name and contact details. If results haven’t been analysed, you can choose if we use those results or not.

10. Who can I contact for questions or want more information?

If you would like to speak to us, please use the contact details below:

Name/Organisation	Position	Telephone	Email
Sarah Jenner	Researcher	0422644593	19280002@students.latrobe.edu.au

11. What if I have a complaint?

If you have a complaint about any part of this study, please contact:

Ethics Reference Number	Position	Telephone	Email
S17-025	Senior Research Ethics Officer	+61 3 9479 1443	humanethics@latrobe.edu.au

<table>
<tr><td colspan="3">EVALUATION OF NUTRITIONAL DATA, BODY COMPOSITION DATA, HEALTH DATA AND PERFORMANCE DATA ROUTINELY COLLECTED FROM ELITE ATHLETES
The research is being carried out by the following researcher:
Sarah Jenner

The research is being carried out in partial fulfilment of PhD under the supervision of Adrienne Forsyth, Regina Belski and Brooke Devlin. The following researchers will be conducting the study:</td></tr>
<tr><td>Role</td><td>Name</td><td>Organisation</td></tr>
<tr><td>Chief Investigator</td><td>Adrienne Forsyth</td><td>La Trobe University</td></tr>
<tr><td>External Investigator</td><td>Regina Belski</td><td>Adjunct La Trobe University</td></tr>
<tr><td>Investigator</td><td>Brooke Devlin</td><td>La Trobe University</td></tr>
<tr><td>Student</td><td>Sarah Jenner</td><td>La Trobe University/Carlton Football Club</td></tr>
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</table>

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- Elite athlete; competing in the Australian Football (AFL), Australian Football Women's (AFLW) and Victorian Leagues (VFL)
- Aged between 13-40 years
- Participate in full to part time training- minimum 15 hours per week.

15. What will I be asked to do?

If you want to take part in this study, we will ask you to consent for use of the information they provide regarding their dietary practices that is routinely collected as a part of clinical practice by the club dietitian. Data will be obtained through face-to-face semi-structured interviews during routine consults with the club dietitian. Where consent is provided, interviews will be recorded using a handheld device by the club dietitian, for data collection and transcription purposes and will be stored securely. The face-to-face semi constructed interviews will take approximately 15 minutes of your time.

16. What are the benefits?

The benefit of you taking part in this study is that the data collected in this study will inform dietetic practice and in the longer term, enable the development of personalised nutrition interventions to help athletes achieve optimal health and performance. The expected benefits to society in general are that the data collected may be published and if so, will help set the context for baseline nutrition knowledge and behaviour of elite athletes in Australia to support the work of coaching staff and dietitians as well as other researchers.

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Nil risks have been associated with current research. You will not be required to do anything extra to participate in this study, only to consent to having your data collected by the club dietitian.

18. What will happen to information about me?

We will collect and store information about you in ways that will not reveal who you are. This means you cannot be identified in any type of publication from this study.

We will keep your information for 7 years after the project is completed. After this time, we will destroy all your data.

We will collect, store and destroy your data in accordance with La Trobe Universities Research Data Management Policy which can be viewed online using the following link: https://policies.latrobe.edu.au/document/view.php?id=106/.

The information you provide is personal information for the purposes of the Information Privacy Act 2000 (Vic). You and your child have the right to access personal information held about you by the University, the right to request correction and amendment of it, and the right to make a compliant about a breach of the Information Protection Principles as contained in the Information Privacy Act.

19. Will I hear about the results of the study?

We will let you know about the results of the study via the team dietitian, who will provide individual feedback as a part of routine practice.

20. What if I change my mind?

At any time, you can choose to no longer be part of the study. You can let us know by:

- Completing the 'Withdrawal of Consent Form' (provided at the end of this document);
- Calling us;
- Emailing us

Your decision to withdraw at any point will **not** affect your relationship with La Trobe University or any other organisation listed.

When you withdraw, we will stop asking you for information. Any identifiable information about you will be withdrawn from the research study. However, once the results have been analysed, we can only withdraw information, such as your name and contact details. If results haven't been analysed, you can choose if we use those results or not.

21. Who can I contact for questions or want more information?

If you would like to speak to us, please use the contact details below:

Name/Organisation	Position	Telephone	Email
Sarah Jenner	Researcher	0422644593	19280002@students.latrobe.edu.au

22. What if I have a complaint?

If you have a complaint about any part of this study, please contact:

Ethics Reference Number	Position	Telephone	Email
S17-025	Senior Research Ethics Officer	+61 3 9479 1443	humanethics@latrobe.edu.au

Consent Form – Declaration by Participant

I (the participant) have read (or, where appropriate, have had read to me) and understood the participant information statement, and any questions have been answered to my satisfaction. I agree to participate in the study, I know I can withdraw at any time. I agree information provided by me or with my permission during the project may be included in a thesis, presentation and published in journals on the condition that I cannot be identified.

I would like my information collected for this research study to be:

☐ Only used for this specific study;

☐ Used for future related studies;

☐ Used for any future studies

☐ I agree to have my interview audio and/or video recorded

☐ I agree to have biospecimens collected

☐ I would like to receive a copy of the results via email or post. I have provided my details below and ask that they only be used for this purpose and not stored with my information or for future contact.

Name	**Email (optional)**	**Postal address (optional)**

Participant Signature

☐ I have received a signed copy of the Participant Information Statement and Consent Form to keep

Participant's printed name	
Participant's signature	
Date	

Declaration by Researcher

☐ I have given a verbal explanation of the study, what it involves, and the risks and I believe the participant has understood;

☐ I am a person qualified to explain the study, the risks and answer questions

Researcher's printed name	
Researcher's signature	
Date	

Withdrawal of Consent

I wish to withdraw my consent to participate in this study. I understand withdrawal will not affect my relationship with La Trobe University of any other organisation or professionals listed in the Participant Information Statement. I understand the researchers cannot withdraw my information once it has been analysed, and/or collected as part of a focus group.

I understand my information will be withdrawn as outlined below:

- ✓ Any identifiable information about me will be withdrawn from the study
- ✓ The researchers will withdraw my contact details so I cannot be contacted by them in the future studies unless I have given separate consent for my details to be kept in a participant registry.
- ✓ The researchers cannot withdraw my information once it has been analysed, and/or collected as part of a focus group

***if you have consented for your contact details to be included in a participant registry you will need to contact the registry staff directly to withdraw your details.*

I would like my already collected and unanalysed data

☐ Destroyed and not used for any analysis

☐ Used for analysis

Participant Signature

Participant's printed name	
Participant's signature	
Date	

Please forward this form to:

CI Name	[INSERT - CI Name]
Email	[INSERT - work email address]
Phone	[INSERT - work phone]
Postal Address	[INSERT - work postal address]

APPENDIX E. The Nutrition for Sport Questionnaire (NSKQ) – full version with supplementary questions

Carlton_Universal Nutrition for Sport Questionnaire (NSKQ)

Start of Block: Demographic questions

Q0.1 What year were you born in?

▼ 1920 (1) ... 2020 (103)

Q0.2 What is your gender?

- Male (1)
- Female (2)

Q0.3 What country were you born in?

▼ Afghanistan (1) ... Zimbabwe (193)

Q0.4 What is your current post-code?

____

Q0.5 What is the highest level of education you have obtained?

- ❍ Primary School (1)
- ❍ I am completed/am enrolled high school (2)
- ❍ I completed/am enrolled in Tafe, Diploma or equivalent (3)
- ❍ University (I completed/am enrolled in a bachelor/undergraduate degree) (4)
- ❍ University (I completed/am enrolled in a honors/masters degree) (5)
- ❍ University (I completed/am enrolled in a doctoral degree) (6)

X→

Q0.6 Have you ever completed any formal studies in human nutrition? This may include a University subject, University course, a specialised course, an online course, Tafe or other diploma

- ❍ Yes (1)
- ❍ No (2)

X→

Q0.7 What is the highest level that you play sport at?

- ❍ State league (2)
- ❍ National league (3)
- ❍ International league (4)
- ❍ Click to write Choice 4 (1)

Q0.8 On average, how many hours do you train per week? (Including all fitness related activities, at and away from your sporting club)

▼ 1 (1) ... 100 (100)

Q0.9 How many years have you been playing the main sport you participate in for? (Include primary school, high school, university)

▼ 1 (1) ... 100 (100)

Q0.10 Researcher specific Question: Are you currently in the first year program?

- ❍ Yes (1)
- ❍ No (2)

Q0.11 How many years have you played football in the AFL?

▼ First Year (1) ... 8 or more (9)

Q0.12 Have any of these individuals ever given you advice regarding your diet? Tick all that apply.

- ☐ Team-mates (1)
- ☐ Coach/Trainer (2)
- ☐ Dietitian/Nutritionist (3)
- ☐ Doctor (4)
- ☐ Friends (5)
- ☐ Family (6)

Q0.13 Rank the top 3 sources of information you rely on regarding nutrition by placing 1, 2, and 3 in the relevant boxes.

______ Academic Journal (1)
______ Athletic Trainer/ Strength and Conditioning Coach (2)
______ Coach (3)
______ Dietitian (4)
______ Nutritionist (5)
______ Doctor (6)
______ Family/Friend (7)
______ Internet Search (8)
______ Mass Media (Magazine, Radio, TV) (9)
______ Social Media (Facebook, Twitter) (10)
______ Team Mates (11)

Q0.14 Does the sporting organisation you are part of provide you with access to nutrition information or nutritionists/dietitians?

- ❍ Nutrition information only (1)
- ❍ Nutrition Information and access to nutritionist/dietitian (2)
- ❍ Neither of the above (3)

Q0.15 Do you think that the sporting organisations should provide members with access to nutrition information or nutritionists/dietitians?

- ❍ Yes, Nutrition information only (1)
- ❍ Yes, Nutrition Information and access to nutritionist/dietitian (2)
- ❍ Neither of the above (3)

Q0.16 What type of support do/would you find useful, please rank from 1 (most useful) to 5 (least useful)?

______ Access to nutrition information relevant to healthy eating (1)
______ Access to nutrition information relevant to sports/training nutrition (2)
______ Access to group presentations by nutritionists/dietitians (3)
______ Individual consultations by nutritionists/dietitians (4)
______ Cooking classes (5)

Q0.17 What is your body mass in kilograms?

____

Q0.18 What is your height in metres?

____

End of Block: Demographic questions

Start of Block: Weight Management

Q1.1 Which nutrient do you think has the most energy (kilojoules/calories) per 100 grams (3.5 ounces)?

- ❍ Carbohydrate (1)
- ❍ Protein (2)
- ❍ Fat (3)
- ❍ Not Sure (4)

Q1.2 The following are statements about weight management. Please select agree, disagree or not sure:

	Agree (1)	Disagree (2)	Not Sure (3)
1. In endurance sports, having the lowest weight possible benefits performance in the long term (1)	❍	❍	❍
2. Increasing protein in the diet is the main dietary change needed when only muscle gain is desired (2)	❍	❍	❍
3. Protein eaten in excess of bodily needs can lead to fat gain (4)	❍	❍	❍

Q1.3 The following are some strategies one might try to lose weight (or reduce body fat). Please indicate if you think these are effective, not effective or you are not sure.

	Effective (1)	Not Effective (2)	Not Sure (3)
1. Increase intake of low-energy foods such as vegetables (1)	❍	❍	❍
2. Swap butter for canola spread (polyunsaturated margarine) (3)	❍	❍	❍
3. Exchange yogurts, muesli/granola bars and fruit snacks for protein bars and shakes (4)	❍	❍	❍
4. Choose lower glyceamic index (GI) carbohydrates (9)	❍	❍	❍
5. Stop eating carbohydrate-containing foods (e.g. rice and pasta) after 4 pm (10)	❍	❍	❍

Q1.4 When weight loss is desired, generally athletes should:

❍ Decrease carbohydrate intake to less than 50 grams (1.7 ounces) per day (1)

❍ Decrease fat intake to less than 20 grams (0.7 ounces) per day (2)

❍ Decrease calories/kilojoules by decreasing carbohydrate, fat and protein (3)

❍ Not Sure (4)

Q1.5 To ensure they meet their energy (kilojoule/calorie) requirements, all athletes should:

- Plan their diet according to their age, gender, body size, sport and training program (1)
- Eat to appetite following their natural hunger and fullness signals (2)
- Eat a minimum of 8000 kilojoules (2000 calories) per day (3)
- Choose foods that are high in carbohydrate (4)
- Not Sure (5)

Q1.6 Which do you think is the best lunch option for an athlete trying to gain weight (muscle)? Assume they are training in the morning and have already had breakfast and a mid-morning snack.

- A 'mass gainer' protein shake and 3 - 4 scrambled eggs (1)
- Pasta with lean mince meat and vegetable sauce,plus a dessert of fruit, yoghurt and nuts (2)
- A large piece of grilled chicken with a side salad (lettuce, cucumber, tomato) (3)
- A large steak and fried eggs (4)
- Not Sure (5)

Q1.7 Which do you think is the best lunch option for an athlete trying to lose weight? Assume they are eating an appropriate breakfast and dinner.

- A side salad with no dressing (lettuce, cucumber, tomato) (1)
- A pure whey protein isolate (WPI) shake made on water (2)
- A mixed meal that includes a small-moderate serving of meat and carbohydrate (e.g. small bowl pasta with lean mince meat and vegetable sauce) plus a large side salad (3)
- Not Sure (4)

End of Block: Weight Management

Start of Block: Macronutrients

Q2.1 How much carbohydrate do you think is recommended for an athlete undertaking a moderate to high-intensity endurance training program for one to three hours per day?

❍ 1 - 3 g carbohydrate per kg (0.016 - 0.048 ounces per lb) body weight per day (1)

❍ 5 - 8 g carbohydrate per kg (0.08 -0.13 ounce per lb) body weight per day (2)

❍ 15 - 25% of total daily kilojoule/calorie intake (3)

❍ 75 - 85% of total daily kilojoule/calorie intake (4)

❍ Not Sure (5)

Q2.2 Do you think these foods are high or low in carbohydrate?

	High (1)	Low (2)	Not Sure (3)
1 Medium Banana (Q2.2_1)	❍	❍	❍
1/2 cup cooked Quinoa (Q2.2_2)	❍	❍	❍
1 Tablespoon Butter (Q2.2_3)	❍	❍	❍
1 Cup Baked Beans (Q2.2_4)	❍	❍	❍

Q2.3 Which of the following foods do you think contains the most carbohydrate?

❍ 1 cup (168 g/5.6 ounces) boiled rice (1)

❍ 2 slices of white sandwich loaf bread (2)

❍ 1 medium (150 g/ 5 ounces) boiled potato (3)

❍ 1 medium (150 g/5 ounces) ripe banana (4)

❍ Not Sure (5)

Q2.4 The following statements are about fat. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Fat is required by the body to make cell membranes and molecules involved in immune function (Q2.4_21)	❍	❍	❍
2. For athletes, no more than 20g of fat should be eaten per day (Q2.4_2)	❍	❍	❍
3. When exercise intensity increases, the relative amount (%) of fat that is burnt to supply the body with fuel increases (Q2.4_3)	❍	❍	❍
4. When exercising at low intensities, fat provides almost all the substrate needed to cover energy costs (Q2.4_4)	❍	❍	❍

Q2.5 Do you think these foods are high or low in fat?

	High (1)	Low (2)	Not Sure (3)
1/2 Cup Cottage cheese (Q2.5_1)	❍	❍	❍
1 Tablespoon Polyunsaturated margarine (Q2.5_2)	❍	❍	❍
1/4 Cup Mixed nuts (Q2.5_3)	❍	❍	❍
1 Tablespoon Honey (Q2.5_4)	❍	❍	❍

Q2.6 The following statements are about protein. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Protein is the main source of energy used by muscles during exercise (Q2.6_1)	❍	❍	❍
2. Vegetarian athletes can meet their protein requirements without the use of protein supplements (Q2.6_2)	❍	❍	❍
3. A well trained athlete needs more protein than a young athlete who is just beginning training (Q2.6_3)	❍	❍	❍
4. Protein absorption in a single sitting is limited (Q2.6_4)	❍	❍	❍
5. A balanced diet with adequate kilojoules/calories (energy) should meet all protein needs (Q2.6_5)	❍	❍	❍

Q2.7 Which of the following foods do you think contains the most protein?

❍ 2 eggs (1)

❍ 100g (3 ounces) raw skinless chicken breast (2)

❍ 30g (1 ounce) almonds (3)

❍ Not Sure (4)

Q2.8 The protein needs of a 100 kg (220 lb) well trained resistance athlete are closest to:

- 75 g (2.7 ounces) per day (1)
- 130 g (4.6 ounces) per day (2)
- 250 g (8.8 ounces) per day (3)
- They should eat as much protein as possible (4)
- Not sure (5)

X→

Q2.9 Do you think these foods are high or low in protein?

	High (1)	Low (2)	Not Sure (3)
100g (3 ounces) Chicken Breast (Q2.9_1)	❍	❍	❍
30g (1 ounce) Yellow Cheese (Q2.9_2)	❍	❍	❍
1 Cup Baked Baked Beans (Q2.9_3)	❍	❍	❍
1/2 Cup Cooked Quinoa (Q2.9_4)	❍	❍	❍

X→ X→

Q2.10 Do you think these foods contain all the essential amino acids needed by the body?

	Yes (1)	No (2)	Not Sure (3)
Beef Steak (2)	❍	❍	❍
Eggs (4)	❍	❍	❍
Lentils (5)	❍	❍	❍
Cow's Milk (7)	❍	❍	❍

X→ X→

Q2.11 The amount of protein in skim milk compared to full cream milk is:

- ❍ Significantly less (1)
- ❍ About the same (2)
- ❍ Significantly more (3)
- ❍ Not Sure (4)

End of Block: Macronutrients

Start of Block: Micronutrients

X→ X→

Q3.1 The following are statements about the role of different micronutrients. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Calcium is the largest structural component of bone crystals (Q3.1_1)	❍	❍	❍
2. Vitamin C acts as an anti-oxidant in the body (Q3.1_2)	❍	❍	❍
3.Thiamine (Vitamin B1) is required for efficient delivery of oxygen to muscles (Q3.1_3)	❍	❍	❍
4. The main role of Iron is the conversion of food into usable energy (Q3.1_4)	❍	❍	❍

X→ X→

Q3.2 The following statements are about the food sources of different micronutrients. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Meat, Chicken and Fish are the best sources of zinc (Q3.2_1)	❍	❍	❍
2. Wholegrain foods are the best sources of vitamin C (Q3.2_2)	❍	❍	❍
3. Fruit and Vegetables are the best sources of calcium (Q3.2_3)	❍	❍	❍
4. Milk, Yogurt and Cheese are the best sources of magnesium (Q3.2_4)	❍	❍	❍

Q3.3 The following statements are about athletes vitamin and mineral requirements. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Athletes have increased magnesium needs due to losses in sweat (Q3.3_1)	❍	❍	❍
2. Women who are menstruating have higher iron needs than men (Q3.3_2)	❍	❍	❍
3. The optimal calcium intake for athletes aged 15 to 24 years is 500 mg (Q3.3_3)	❍	❍	❍
4. A physically fit person eating a nutritionally adequate diet can improve their performance by eating more vitamins and minerals (Q3.3_4)	❍	❍	❍
5. Vitamins provide the body with energy (kilojoules/calories) (Q3.3_5)	❍	❍	❍

End of Block: Micronutrients

Start of Block: Sports Nutrition

Q4.1 Athletes should drink water during activity in order to:

- ❍ Maintain plasma (blood) volume (1)
- ❍ Prevent dry mouth (2)
- ❍ Maintain sweat volume (3)
- ❍ All of the above (4)
- ❍ Not Sure (5)

Q4.2 Regarding fluid intake during physical activity, current recommendations encourage athletes to:

- ❍ Drink 50 - 100 ml (1.7 - 3.3 fluid ounces) every 15 - 20 minutes (1)
- ❍ Suck on ice cubes rather than drinking during practice (2)
- ❍ Drink sports drinks (e.g. powerade) instead of water when exercising (3)
- ❍ Drink to a plan, based on body weight changes during training sessions performed in a similar climate (4)
- ❍ Not Sure (5)

Q4.3 How much carbohydrate should fluid consumed for hydration purposes (during exercise) contain?

- ❍ None (1)
- ❍ At least 1 - 2 % carbohydrate (2)
- ❍ At least 4 - 8 % carbohydrate (3)
- ❍ Not Sure (4)

Q4.4 How much sodium (salt) should fluid consumed for hydration purposes (during exercise) contain?

- ❍ At least 11 - 25 mmol/L (~ 250 - 575 mg/L) (1)
- ❍ At least 4 - 8 mmol/L (~ 90 - 185 mg/L) (2)
- ❍ None (3)
- ❍ Not Sure (4)

Q4.5 Before competition, athletes should aim to consume foods that are high in:

- ❍ Fluids, fat and carbohydrate (1)
- ❍ Fluids, fibre and carbohydrate (2)
- ❍ Fluids and carbohydrate (3)
- ❍ Not Sure (4)

Q4.6 The following statements are about carbohydrate consumption during exercise. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Consuming carbohydrate during exercise can REDUCE ability to develop strength and muscle gains (Q4.6_1)	❍	❍	❍
2. In events lasting 60 - 90 minutes, 30- 60 g (1.0 - 2.0 ounces) of carbohydrates should be consumed per hour (Q4.6_2)	❍	❍	❍
3. Consuming carbohydrate during exercise will assist in maintaining blood glucose levels (Q4.6_3)	❍	❍	❍

Q4.7 Stomach discomfort is sometimes reported by athletes who eat during exercise. Which of the following is NOT a good strategy to avoid discomfort:

❍ Having energy gels instead of water or sports drinks (1)

❍ Consuming small volumes at regular intervals (2)

❍ Choosing sports drinks/foods with a mixture of types of carbohydrate (e.g. fructose and sucrose) (3)

❍ Not Sure (4)

Q4.8 During a competition, athletes should aim to consume foods that are high in:

- Fluids, fibre and fat (1)
- Fluids and protein (2)
- Fluids and carbohydrate (3)
- Not Sure (4)

Q4.9 Which of the following best meets the recommendations for a snack consumed during high-intensity exercise lasting around 90 minutes?

- A protein shake (1)
- A ripe banana (2)
- 2 Boiled eggs (3)
- A handful of nuts (4)
- Not Sure (5)

Q4.10 After a competition, athletes should aim to consume foods that are high in which macronutrient/s?

- Protein, carbohydrate and fat (1)
- Only protein (2)
- Only carbohydrate (3)
- Carbohydrate and protein (4)
- Not Sure (5)

Q4.11 How much protein do you think experts recommend athletes should have after completing a resistance exercise session?

- 0.3g/kg body weight (~ 15 - 25 g [0.53 - 0.88 ounces] for most athletes) (1)
- 1.0 g/kg body weight (~ 50 - 100 g [(1.9 - 2.3 ounces)] for most athletes) (2)
- 1.5g/kg body weight (~ 150 – 130 g [5.3 – 10.6 ounces] for most athletes) (3)
- Not Sure (4)

End of Block: Sports Nutrition

Start of Block: Supplementation

Q5.1 The following are statements about athletes' needs for particular micronutrient supplements. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Vitamin C should be routinely supplemented by athletes (Q5.1_1)	❍	❍	❍
2. B Vitamins should be taken when feeling low in energy (Q5.1_2)	❍	❍	❍
3. Salt tablets should be used by athletes that get a cramp during exercise (Q5.1_3)	❍	❍	❍
4. Iron tablets should be taken when a player feels extremely tired and is pale (Q5.1_4)	❍	❍	❍

Q5.2 The purity and safety of all supplements are tested before sale.

- ❍ Agree (1)
- ❍ Disagree (2)
- ❍ Not Sure (3)

Q5.3 Supplement labels may contain false or misleading information.

- ❍ Agree (1)
- ❍ Disagree (2)
- ❍ Not Sure (3)

Q5.4 The following statements are about the reported benefits of performance-enhancing supplements. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. Creatine reduces perceived effort of exercise by acting on the central nervous system (Q5.4_1)	❍	❍	❍
2. Caffeine improves efficiency of muscles at a given rate of oxygen delivery (Q5.4_2)	❍	❍	❍
3. Beetroot Juice (nitrates) decrease muscle breakdown and reduce muscle soreness (Q5.4_3)	❍	❍	❍
4. Beta-Alanine produces carnosine, a protein that can buffer ("soak up") acid by-products produced during high-intensity activity (Q5.4_4)	❍	❍	❍

Q5.5 In relation to improving sporting performance, which of the following supplements do you think has NOT been supported by a strong body of scientific evidence?

- ❍ Caffeine (1)
- ❍ Ferulic acid (2)
- ❍ Bicarbonate (3)
- ❍ Leucine (4)
- ❍ Not Sure (5)

Q5.6 Which of the following supplements do you think is banned by the WORLD ANTI-DOPING AGENCY (WADA)?

- Caffeine (1)
- Bicarbonate (2)
- Carnitine (3)
- Glycerol (4)
- Not Sure (5)

End of Block: Supplementation

Start of Block: Alcohol

Q6.1 How many grams/ fluid ounces of ethanol (pure alcohol) does a standard drink generally contain?

- 1 - 2 g/ 0.03 - 0.06 fluid ounces (1)
- 8 - 14 g/ 0.3 - 0.6 fluid ounces (2)
- 30 - 50 g /1.2 - 2.0 fluid ounces (3)
- Not Sure (4)

Q6.2 Which of the following do you think is an example of a "Standard Drink"?

- 30 - 45 ml/1 - 1.5 fluid ounces of pure spirits (1)
- One quarter of a bottle (175 ml/ 6 fluid ounces) of red wine (2)
- A pint (425 ml/ 14 fluid ounces) of full strength beer (3)
- Not Sure (4)

Q6.3 When consumed as part of the diet, pure alcohol (ethanol) contains calories/kilojoules and, therefore, can lead to weight gain.

- Agree (1)
- Disagree (2)
- Not Sure (3)

Q6.4 For individuals who choose to drink alcohol, to reduce the risk of alcohol-related harm over a lifetime, no more than [ ] standard drinks should be consumed per day:

- ❍ Two (1)
- ❍ Three (2)
- ❍ Four (3)
- ❍ Not Sure (4)

Q6.5 The following statements are in relation to alcohol consumption. Please select agree, disagree or not sure.

	Agree (1)	Disagree (2)	Not Sure (3)
1. If someone does not drink at all during the week, it is okay for them to have five or more drinks on a Friday or Saturday night (Q6.5_1)	❍	❍	❍
2. Drinking large amounts of alcohol can reduce recovery from injury (Q6.5_2)	❍	❍	❍
3. Alcohol has been shown to increase urinary losses during post-exercise recovery (Q6.5_3)	❍	❍	❍

Q6.6 "Binge drinking" (also referred to as heavy episodic drinking) is generally defined as:

- ❍ Having two or more standard alcoholic drinks on the same occasion (1)
- ❍ Having four to five or more standard alcoholic drinks on the same occasion (2)
- ❍ Having seven to eight or more standard alcoholic drinks on the same occasion (3)
- ❍ Not Sure (4)

End of Block: Alcohol

Start of Researcher Specific Questions

Start of Block: Researcher Specific Questions- Cooking Skills/Knowledge

Q7.1 On a scale of 1-10, how confident do you feel about your current skills to cook healthy meals to meet training demands (*With 1 being not confident at all and 10 being extremely confident*)?

	0	1	2	3	4	5	6	7	8	9	10
Confidence ()											

Q7.2 On a scale of 1-10, how confident do you feel that you have the knowledge to cook healthy meals to meet the training demands (*With 1 being not confident at all, and 10 being extremely confident)?*

	0	1	2	3	4	5	6	7	8	9	10
Confidence ()											

Q7.3 During a normal training week, how often do you prepare and cook a meal at home?

- Every night (1)
- 4-6 times a week (2)
- 2-3 times a week (3)
- Once a week (4)
- Never (5)

Q7.4 Which of the following options best describes your current cooking skills?

- ❍ I can confidently prepare meals from basic ingredients (i.e. Cooking Bolognese from scratch using basic ingredients) (5)
- ❍ I can confidently prepare meals from ready-made ingredients (i.e. Use of pasta sauces, simmer sauces etc.) (6)
- ❍ I can confidently buy and heat ready-made meals (i.e. Frozen dinners, Light and easy etc.) (4)
- ❍ I do not cook meals at home (i.e. Buy or meals prepared by others) (3)

X→

Q7.5 Answer, True, False or Not Sure to the following statements.

	True (1)	False (2)	Not Sure (3)
I know how to handle a knife safely when preparing meals (Q7.5_1)	❍	❍	❍
I know how to prepare meals from a recipe (Q7.5_2)	❍	❍	❍
I know how to substitute ingredients to make recipes healthier (Q7.5_3)	❍	❍	❍
I know how to safely store ingredients and left over meals (Q7.5_4)	❍	❍	❍
I know how to read a food label and choose the best product (Q7.5_5)	❍	❍	❍
I know how to use spices and herbs to flavour meals (Q7.5_6)	❍	❍	❍

End of Block: Cooking Skills/Knowledge

Start of Block: Researcher Specific Questions- Shopping/Label reading skills

Q8.1 How often do you write a grocery list before undertaking a grocery shop?

- Every time (1)
- On occasion (2)
- Only if I am following a recipe (3)
- Never (4)

Q8.2 On a scale of 1-10, how would you rate your confidence in being able to read and understand a nutrition information panel? (*With 1 being not confident at all, and 10 being extremely confident)*

	0	1	2	3	4	5	6	7	8	9	10
Image:Nutrition information label eat for health ()											

End of Block: Start of Block: Researcher Specific Questions- Shopping/Label reading skills

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Start of Block: Start of Block: Researcher Specific Questions- Carbohydrate Versus Body comp

Q9.1 In how many of your daily meals do you include a carbohydrate source?

- Every main and mid meals/snacks (1)
- Every main meal (2)
- Only on main training days (3)
- Nil main or mid meals/snacks (4)
- I am not 100% confident what a carbohydrate is, so not sure (5)

Q9.2 What dietary strategies do you undertake to meet body composition goals (*i.e. Decrease body fat, increase lean muscle etc.*) Please select all that apply.

- ▢ Low carbohydrate diet (1)
- ▢ Periodise carbohydrate intake (i.e. High versus low days). (2)
- ▢ Restrict overall food intake before DEXA scan (i.e. 1 week) (3)
- ▢ I do not change my diet (4)

End of Block: Researcher Specific Questions – Carbohydrate Versus Body Composition

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Start of Block: Researcher Specific Questions- Portions

X→

Q10.1 How many serves of vegetables do you consume on a daily basis (One serve = ½ cup cooked OR 1 cup raw)

- ❍ 5 or more serves per day (1)
- ❍ 3-4 serves, per day (2)
- ❍ 1-2 serves, per day (3)
- ❍ Nil serves, per day (4)

X→

Q10.2 How much meat *(i.e. red meat, chicken, fish etc.)* would you usually have as a part of a main meal? (100 g = size of small palm = size of a deck of cards).

- ❍ 100-150 g (1)
- ❍ 200 – 250 g (2)
- ❍ 300 – 350 g (3)
- ❍ 400 g + (4)

End of Block: Researcher Specific Questions- Portion

APPENDIX F: Proposed Dual Energy X-ray Absorptiometry standardised protocols

Background:

Dual Energy X-ray Absorptiometry scans have been used since the 1980s specifically for the assessment of bone including bone mineral density. More recently DXA scans have become more commonly used within professional athlete populations to assess body composition including Fat free soft tissue mass (FFSTM, g), Fat mass (FM, g), Bone Mineral Content (BMC, g) and Body fat percentage (BF%). Validation studies undertaken within healthy populations have found that DXA scans have a greater level of accuracy when compared to other body composition assessment methods such as bioelectrical impedance analysis (BIA) and skinfold measures.

Standardised Protocols

DXA machine: Lunar Pencil Beam, GE Health, Lunar Corp, USA

Athletes' body composition including whole body FFSTM, FM and BMC, as well as regional profile (i.e. arms and legs) will be assessed using a Lunar Pencil Beam machine, with a standard analysis software used to analyse scans (Software SmartScan). All procedures will be standardised and aligned with recommendations advocated by the Australian & New Zealand Bone & Mineral Society (ANZBMS) and other relevant research (1-3). Prior to scanning the DXA machine will be calibrated using a criterion phantom device, as per manufacturer guidelines. Athletes prior to scan will be instructed to additionally undertake a hydration test (i.e. Urine Specific Gravity test) to ensure hydration is optimal prior to scan. Athletes body mass (kg) will additionally measured and documented by the DXA technician. Please see Appendix G. for specific athlete preparation protocols.

Positioning

To minimise scanning errors, a standardised positioning protocol will be used, with all scans completed and analysed by one designated DXA technician. Guided by the DXA technician, athletes will be positioned with their head and torso parallel to the long axis of the scan bed. Athletes will be asked to position hands into a pronated flat position, with legs rotated internally at the hip bone (i.e. at 45 °) and secured with straps. Athletes who exceed the length of the scanning bed (i.e. height over 198 cm) will be positioned according to protocols validated by Santos et al. (2013). These protocols require two scans to be undertaken, the first scan to measure the athletes head and jaw (approximately 80 cm) and the second scan to measure torso and limbs, with the athlete's head slightly positioned outside of the DXA bed (2). Once positioned the DXA technician will perform the scan, which will take approximately 10 minutes (i.e. 15 minutes for 'two scans'). Data will be analysed manually by the same DXA technician and interpretation of data will be undertaken with relevant support staff (i.e. Sports Dietitian).

References:

1. ANZBMS. Clinical Densitometry Course Notes. (2017) Australia and New Zealand Bone Mineral Society. Australia
2. Santos D, Gobbo L, Matias C, Petroski E, Gonçalves E, Cyrino E, Minderico, C, Sardinha, L, Silva, A. Body composition in taller individuals using DXA: A validation study for athletic and non-athletic populations. Journal of Sports Sciences. 2013;31(4):405-413.
3. Nana A, Slater G, Hopkins W, Halson S, Martin D, West N, Burke, L. Importance of Standardized DXA Protocol for Assessing Physique Changes in Athletes. International Journal of Sport Nutrition and Exercise Metabolism. 2016;26(3):259-267.

APPENDIX G. Dual Energy X-ray Absorptiometry preparation guidelines for athletes

Preparing for your DXA scan

The day before your DXA scan:

- You will be provided with information regarding the day and time of your DXA scan 1-day prior to scan by team dietitian (*these are updated guidelines).
- Please eat normally and stay well hydrated.

On the day of your scan (morning scans)

Preparation

- Please ensure you are fasted for your DXA scan (i.e. your last meal will be the night before). Please consume breakfast post scan.
- Please go to the bathroom and empty bladder before your DXA scan

Clothing

- Do not exercise before scan (i.e. return to club and prepare for DXA scan)
- Please wear loose and thin clothing (i.e. training top and shorts).
- Ensure that clothing has no metal linings, buttons or zippers.
- Please remove all jewellery, watches and any objects from your pockets before your scan.

NB: If you do consume any foods before your scan, please make note of foods consumed or provide this information to your team dietitian.