"Changes in Anthropometry, Upper Body Strength and Nutrient Intake in Professional Australian Football Players During a Season" by Bilsborough JC et al.
International Journal of Sports Physiology and Performance

Abstract

The purpose of this study was to examine the seasonal changes in body composition, nutrition, and upper body strength in professional Australian Football (AF) players. A prospective longitudinal study examined changes in anthropometry (body mass, fat-free soft tissue mass (FFSTM) and fat mass (FM)) via dual-energy X-ray absorptiometry (DXA) five times during an AF season (start-preseason, mid-preseason, start-inseason, mid-inseason, end-inseason) in 45 professional AF players. Dietary intakes and strength (bench press and bench pull) were also assessed at these time points. Players were categorised as experienced (>4 y experience, N=23) or inexperienced (<4 y experience, N=22). FM decreased during the preseason but was stable through the inseason for both groups. %FFSTM was increased during the preseason and remained constant thereafter. Upper body strength increased during the preseason and was maintained during the inseason. Changes in upper body FFSTM were related to changes in UB strength performance (r = 0.37-0.40). Total energy and carbohydrate intakes were similar between the experienced and inexperienced players during the season, but there was a greater ratio of dietary fat intake at the start-preseason point, and an increased alcohol, reduced protein and increased total energy intake at the end of the season. The inexperienced players consumed more fat at the start of season and less total protein during the season compared to the experienced players. Coaches should also be aware that it can take >1 y to develop the appropriate levels of FFSTM in young players and take a long-term view when developing the physical and performance abilities of inexperienced players.

Word count: 4775

Abstract word count: 255

Number of tables: 3

Number of figures: 1

Introduction

Australian Football (AF) is a field-based, collision sport requiring well-developed capacities of strength, power, speed and endurance. Whilst there are large differences between positions, professional AF players typically travel ~11.1–12.8 km during matches at an average speed of 108-128 $m \cdot min^{-1}$ [1,2]. Moreover, the activity profile of AF matches is very stochastic with professional players completing many intense accelerations and decelerations which often include changes of direction [1]. In addition, AF players also complete several physically demanding skills including kicking, jumping, tackling, jostling and colliding with opponents [3,4]. Due to these demands, professional AF players need to develop their physical capacities to allow them to cope with match play.

Australian Football players competing at higher levels have been reported to be heavier, have greater fat-free soft tissue mass (FFSTM) [5,6] and increased strength and power [7,8] compared to their lower level counterparts. Strong correlations have also been observed between whole body and segmental FFSTM and maximal upper body strength and jumping power [9]. Due to these relationships, one of the main goals for training many young AF players after being recruited into professional clubs is to increase FFSTM [10], along with muscular strength and power. However, despite the common perceptions from strength and conditioning coaches that younger AF players have difficulty developing FFSTM and maintaining these characteristics during the inseason, no studies have examined the longitudinal changes in these characteristics in professional AF players at various stages of their career.

Previous studies from professional athletes from other field-based collision sports such as rugby league [11], have shown that players increase FFSTM and decrease FM during the preseason period of training, whilst these changes were reversed during the later period of the inseason. Similarly, earlier research from soccer players using skinfold methods [12] and

DXA [13], have reported reductions in FM during the preseason and loses in FFSTM and increases in FM in the later part of the inseason. It has been suggested that these changes may be due to changes in training program content, such as reduced training loads and strength training volume and/or alterations in dietary practices [13]. At present however, no studies have directly examined these factors in AF professional players.

Through monitoring changes in training dose, body composition and performance during a season, strength and conditioning coaches may be able to determine the effectiveness of training at the group and individual level. However, at present there is no contemporary information available on the changes in these variables in AF players at any level. Therefore the aim of this study was to assess the seasonal changes in body composition, upper body strength and dietary intakes during an entire AF season. A secondary aim was to compare these changes between younger, inexperienced and older, experienced AF players. It was anticipated that the experienced players would have greater FFSTM, %FFSTM and upper body strength than the inexperienced players. It was also expected that the inexperienced players would have greater increases in FFSTM and strength than the experienced players during the preseason.

Methods

Subjects

Forty-five professional (age 22.8 ± 3.0 years, mass 86.8 ± 7.9 kg, stature 188 ± 7 cm) AF players from the same professional AFL club (Carlton Football Club, Carlton, Victoria, Australia) were recruited for the study. The players were subdivided into experienced (contracted to an AFL club ≥4 y, 83±52 AFL games, N = 23) and inexperienced (contracted to an AFL club <4 y, 8±12 AFL games, N = 22) groups. The methods for the study were approved by the University of Technology, Sydney (UTS) ethics committee and by the corresponding club involved. All participants provided written informed consent prior to commencing the study.

Design

This prospective longitudinal investigation assessed upper body strength and body composition in elite AF players. Longitudinal changes in dietary intake were also assessed. Players were assessed five times during a competitive season: 1) start of preseason (November), mid preseason (January), end of preseason / start of inseason (April), mid-inseason (July) and end of inseason (September). Upper body strength was assessed by a one repetition maximum (1RM) bench press and bench pull. Body composition measures of total body and regional composition measures of FFSTM, FM and bone mineral content (BMC) were assessed using a pencil beam dual energy X-ray absorptiometry (DXA, Lunar DPX-IQ, General Electric, Lunar Corp, USA) on the same day as the strength measures.

The training program during the observation period was set by the team coaches and was not influenced by this study. During the preseason the players typically completed 2–4 resistance sessions, 2–4 skill-based sessions and 2–3 cross-training sessions per week. Throughout the inseason period the players typically completed 1–2 recovery sessions, 2–3 resistance sessions, 2–3 skill-based sessions, 1–2 cross training sessions and a competitive match each week. In addition, the players participated in 2–3 injury prevention sessions (i.e. jump and land training, Pilates, water mobility and proprioceptive training) each week throughout 52 weeks. The training year was divided into five phases, the preparation phase (weeks 1–4), early preseason (weeks 4–13), late preseason (weeks 14–23), early competition (weeks 24–33) and late competition (weeks 34–44). Both the overall (i.e. including all training sessions) and resistance training session-RPE training loads were calculated [14]. In addition, the resistance training external loads were recorded for each strength training session by summation of the load (i.e. mass x repetitions x sets) for each exercise in a player's training program.

The strength program was designed with a higher volume load during the preseason. Despite the individualisation of the program for specific players, all participants followed undulating model of periodisation where aspects of maximum strength (3–4 sets, 1–4 repetitions, 90–100% of 1RM), hypertrophy (4–5 sets, 8–12 repetitions, 85% of 1RM) and power (3–4 sets, 3–6 repetitions, 30–60% 1RM) were trained in 4 week blocks. To accommodate a players fatigue from weekly games during the competition phase of the season, lower body resistance loads were reduced. Specifically, the players were restricted to one legs training session early in the week [combined with a moderate upper body session (3–4 sets, 8–12 repetitions, 60–80% of 1RM)]. The players also completed another resistance training session mid-week (2–6 sets, 3–10 repetitions, 30–80% of 1RM), and specifically identified players completed an extra upper body session later in the week.

Each player's anthropometric profile [regional (i.e. arms, trunk and legs), and whole body FFSTM, FM and BMC] was assessed with a pencil beam DXA (Lunar DPX-IQ, General Electric, Lunar Corp, USA) using standard analysis software (Software SmartScan Version 4.7e, Lunar Radiation Corporation, Madison, USA) according to methods described elsewhere [15]. All scans were conducted in a rested and hydrated state with instructions to refrain from a meal 3-4 hours prior to any scan. Scans were completed between 6:00 and 11:00 over a two-day period at each scanning point. Each participant was scanned at the same time of day for all sessions throughout the study period. The same technician analyzed all scans. The coefficients of variation (CV) of repeated total whole body DXA measurements were body mass (kg, 0.34%), BMC (g, 1.49%), FFSTM (g, 0.48%) and FM (g, 5.85%).

Details of regional reliability and validity of the DXA measures in AF players have also been reported elsewhere[16] .

To assess upper body strength, a 1RM for bench press and a bench pull were performed. All players followed a standardized warm-up period for 15 minutes and then commenced a series of lifts for each of the bench press and bench pull as warm ups in preparation for the testing protocols. The following protocol was followed for each lift. Each exercise required 6 repetitions at 50% of 1RM, 4 repetitions at 60% of 1RM, 3 repetitions at 70% 1RM, 2 repetitions at 80% 1RM followed by 1 repetition at 90% 1RM. The player then attempted 1 repetition at 100% and if successful would increase loads by increments of 2.5 kg. The bench press was completed first until 1RM was determined, followed by the same procedure for the bench pull exercise. Rest between each progression was 10 minutes. For the bench press, participants used a self-selected handgrip and lowered the bar to a 90º angle at the elbow. During the bench pull, the participants were instructed to have the chest in contact with the bench at all times. Once lying on the bench, participants would use a slightly wider than shoulder width grip and pull the bar directly upwards where a successful lift constituted the bar coming in contact with the underside of the bench. The time period between each lift was 4–6 minutes. The test was terminated when the player failed twice to lift a particular weight.

At each testing occasion the player’s nutrient intake was assessed using a 24-h recall method, where subjects were asked to recall their previous 24-h food intake for three consecutive days (including one day on a week-end and two week days). This data was checked by a follow-up interview with an experienced nutritionist. A standard format was used for each 24-h recall according to the principles described previously[17]. A 3-day average for total energy, macronutrients, and alcohol consumption was determined for each player.

Prior to the study, the players were given verbal and written instructions for completing food records during an educational session. The educational session focused on proper methods to accurately assess and record food intake. The instruction included visual aids on serving sizes using standardized food models and a review of all household measures (i.e., teaspoon, tablespoon, cup etc.). The subjects also received handouts of the same information to aid in recording all diet records. The handouts included a checklist to ensure the following: that information on all consumed foods and beverages was recorded in the correct units; brand names were specified and locations where all recorded items were eaten (e.g. whether at home or at a restaurant/cafe) were indicated. The players were encouraged to record the names of specific restaurant menu items to allow for the most accurate nutrient analysis of their diet records.

Statistical Analyses

All data are presented as mean ± standard deviation (SD) unless otherwise stated. Before using parametric statistical test procedures, the assumptions of normality and sphericity were verified. A two-way factorial ANOVA assessed differences between the playing levels (experienced, inexperienced) in these measures. A Bonferroni post hoc was used to locate group differences. Partial eta squared (n^2) effect size statistics were employed adopting the following criteria to interpret the magnitude of differences between groups; 0.01 small, 0.06 medium and >0.15 large. Relationships between variables of interest were evaluated using Pearson's correlation coefficient (r). The magnitude of the correlations was also determined using the following scale: r <0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; >0.9, nearly perfect; and 1, perfect. Statistical significance for all analyses was defined by $p \leq 0.05$.

Results

Table 1 shows that training loads were higher at the start and mid-preseason compared to all other periods. The end-season loads were also lower than the end-preseason and mid-competition phase. Moreover, greater training loads were undertaken in the preseason period compared to the competition period, with higher loads, session-RPE, and resistance training loads completed by the inexperienced players compared to the experience players. The inexperienced players completed more upper body resistance session-RPE and resistance training load than the experienced players.

At the commencement of the preseason, experienced players were significantly older with a higher body mass and FFSTM than their inexperienced counterparts. The experienced and inexperienced groups had similar %FFSTM for whole body, trunk and regional segments (Table 2). Similarly, both the experienced and inexperienced players showed significant FM reduction during the preseason phases of training, which was maintained through until the end of the season. There were no significant changes in FFSTM during the competition period. However, %FFSTM increased during the preseason and then maintained during the competition phases. There were small reductions in appendicular FM which increased regional %FFSTM from the mid-competition to the end of season.

The experienced players had greater absolute bench press than inexperienced counterparts (Figure 1A). Bench press performance improved in the inexperienced players during the preseason and was maintained until the end of the season. There were no significant changes in either absolute or relative bench press performance in the experienced players. In contrast, absolute and relative bench pull performance improved in both groups from during the preseason (Figure 1C, D). Changes in upper body FFSTM between each test occasion were related to changes in upper body strength performance (Δ Bench press: r =

0.37; Δ Relative bench press: r = -0.24; Δ Bench pull: r = 0.40; Δ Relative bench pull: r = -0.38).

Table 3 shows the changes in macronutrient and energy intake during the season for experienced and inexperienced professional AF players. There were no significant differences in energy intake or carbohydrate intake (g/kg) between groups or over time. However, the inexperienced players had a higher fat intake than the experienced players, with higher intakes at the start of the season compared to all other testing occasions. In contrast, the experienced players had greater protein intake (g/kg) compared to the inexperienced players and the total protein intake was lower at the end of season compared to all other periods. Alcohol consumption was higher at the end of the season compared to all other testing periods.

Discussion

The main purpose of the present investigation was to assess the changes in anthropometry, upper body strength, and dietary intakes during an entire AF season. We also examined if there were differences in these measures between younger inexperienced and older, experienced AF players. The main findings were that the players decreased FM during the preseason and maintained lower FM throughout the competition period without significant changes in total body mass or FFSTM. However, the FFSTM was significantly different between groups at each time point of the season. Similar to the FFSTM, upper body strength increased during the preseason and was maintained during the inseason and these changes were correlated with variations in both whole-body FFSTM and upper body FFSTM. The player's energy and carbohydrate intakes were also similar between the experienced and inexperienced players, but there were greater fat intakes at the start of the season with increased alcohol and reduced protein intake at the end (post) of the season. The inexperienced players consumed more fat at the start of season and less total protein during the season compared to the experienced players.

Both the experienced and inexperienced players reduced FM and increased %FFSTM during the preseason, but maintained %FFSTM during the competition season. Whilst there was large inter-individual variation in FFSTM (preseason 1.8 ±3.3%, competition season -0.3±6.6%) and fat (preseason -11.2 ±18.5%, competition season 8.9±33.5%), there was no difference between the experienced and inexperienced groups. The only previous report on seasonal changes in body composition in AF players used skinfold analysis to show that differences in the seasonal variation of body composition between players from three different levels of AF competition [18]. In contrast to the present observations, this earlier study showed that elite professional AF players had small significant gains in fat free mass during the preseason but no changes in body fat. It is likely that differences in training status, the level of professional support provided to the players and training stimulus applied in the present study explains the differences to the previous research.

In agreement with the present findings, recent studies have shown increases in FFSTM and decreases in FM during a preseason of rugby league training [19] but deceases in FFSTM towards the end of the competition season [11]. Similarly, elite soccer players [13,20] have shown decreases of FM and increases in FFSTM during preseason training. In the current study, the players completed the highest session-RPE and resistance training loads during the Prep and Early Preseason phases of training, which is a likely explanation why the greatest changes in body composition occurred during this period. The greater fat intake at the start of the preseason may also explain the higher FM in both the experienced and inexperienced groups at the start of the season. Furthermore, the off-season period where strict training loads and food intake monitoring are not adhered too may explain higher levels of fat mass at the start of the season.

The relatively stable FFSTM during the season is most likely due to the high training status of the professional athletes in this study. We initially expected to observe larger increases in FFSTM in the inexperienced players compared to the experienced players. However, in contrast to our initial hypothesis, the inexperienced players demonstrated similar seasonal variations in body composition as the experienced group. These comparable changes were observed despite the inexperienced players also completing higher resistance training loads (both session-RPE and external load) compared to the experienced players throughout the entire season.

It has recently been estimated from indirect measures that professional AF players expend 174 ± 11 kJ/kg during the inseason training week, which is higher than the present observations [21]. Whilst it is difficult to make precise calculations of energy balance in the present study, it is possible that the lack of significant changes in FFSTM during the study may be partly explained by the level of energy availability (i.e. 144 ±60 kJ/kg) and moderately low relative carbohydrate intake during the study (i.e. 4.1 ±1.6 g/kg). On average the players in the present study trained ~1–3 h/day each training day during the preseason, and this was reduced to ~1–2 h each training day during the competition season. In a recent review, Mujika and Burke [22] reported that carbohydrate intakes for team sport athletes training 1–3 h/day should be ~6–10 g/kg each day. Moreover, Holway and Spriet [23] reported that the mean carbohydrate intake relative to body mass from 46 studies examining various male team sport athletes was 5.6 ±1.3 g/kg/day. Based on these reports, the carbohydrate intakes may not have been suboptimal as an influencer of energy availability, and this may partly explain why there were not larger increases in FFSTM during the year. Similar observations have been made during the preseason training period in women football players [24], where the players failed to meet the recommended carbohydrate intakes during rigorous twice-a-day training. It is possible that higher carbohydrate intakes would contribute to greater energy availability and this may be required for greater increases in FFSTM in professional AF players.

Surprisingly, the present results also showed that the players did not adjust total energy or carbohydrate intakes in relation to alterations in training loads. It is important to acknowledge however, that there is typically a large variation in daily training loads within a training week or cycle, where days of higher and lower training loads are often alternated. For example, it is common that heavy training days of 2–3 sessions are often followed by recovery days (i.e. 0–1 session). We are unable to determine if there were day-to-day adjustments in nutrition according to these changes in load. Nonetheless, the present results provide a unique global view of the correspondence between the energy intake and training dose during a season. Future studies could examine if there are daily variations in energy intakes according to exercise demands, as has previously been shown with elite female cyclists [25]. Future work could also examine the efficacy of periodising energy and macronutrient intake on physical and performance outcomes.

There is good evidence to suggest that endurance and strength athletes require additional protein to synthesize new muscle or repair muscle damage [26]. It has been recommended that athletes have protein intakes in the range of 1.3–1.8 g/kg/day to maximize muscle protein synthesis. In the present study both the experienced and inexperienced consumed sufficient protein to meet these requirements, with the mean intake during the study being 1.91 ±0.9 g/kg. Whilst speculative, the high protein intakes reported by these players may have been necessary to cope with periodic energy deficits, as it has been suggested that protein requirements have been shown to increase during periods of low energy availability [27]. Based on the present results, it would seem that greater focus should be given to ensure total energy intake be increased through greater amounts of carbohydrate rather than protein are consumed in AF players during periods of heavy training and especially when the focus is on increasing FFSTM.

In accordance with previous research showing that players at higher levels of competition have greater %FFSTM [5,9], the present results show the experienced players have higher %FFSTM compared to the inexperienced players. These differences are most probably due to an increased training (specifically resistance training) history of the experienced players compared to the inexperienced group. Indeed, the experienced players had 5.7 ±2.4 y experience in a professional football club, whilst the inexperienced players had only 0.8 ±0.9 y in a professional training program. We speculate from the present observations that the benefits of consistent training and appropriate nutrition appear to be important for the long-term development of body composition in professional AF players. Future studies should assess changes in body composition and performance variables over several season to provide a better understanding of the evolution of young professional AF players.

There was an increase in absolute bench pull, but not bench press performance during the season, with the experienced players showing increased absolute performance compared to the inexperienced group during the study. Interestingly, both absolute and relative bench press strength did not change significantly over the entire season with the experienced group. Although not statistically significant, the inexperienced player’s relative strength tended to increase in both exercises over the preseason. These observations are similar to the findings of Hrysomallis and Buttifant [8] who reported no changes in bench press strength in both experienced and inexperienced professional AF players during an entire season. Similarly, several other studies from a variety of collision field based sports such as elite rugby union [28] rugby league [29] and American football [30] have also reported that upper body strength is maintained during the competition season of their respective sports.

It has previously been suggested that strength over a competitive season in professional rugby players seem to be related to the frequency/volume of the training stimulus, requiring increased force outputs or load [28]. In the current study, the periods of greatest increases in bench pull performance occurred during the periods of greatest resistance training loads and there was maintenance in the performance levels during the season when training loads were reduced. However, it was surprising that there were not greater increases in strength performance in the inexperienced players in this study, as they completed greater strength training loads throughout the season. We also observed moderate relationships between changes in %FFSTM and changes in relative strength performance, highlighting the importance for increasing muscle mass to gain strength improvements. When the present observations are taken in the context of the negative effects of short-term energy deficits on myofibrillar protein synthesis following resistance training[27], it is recommended that players avoid periods of short-term energy deficits when aiming to increase FFSTM. This would be important for AF players aiming to increase FFSTM and muscular strength. Additionally, any changes in energy intake should be carefully titrated to compensate for increases in exercise energy expenditure to avoid the negative effects short-term energy deficits in players aiming to increase FFSTM.

The energy intakes reported in the present study (11.1–13.9 MJ/day) are lower than a previous reports from elite AF players which showed that players consumed 13.2–14.2 MJ/day [10,31,32] whilst athletes from other team sports consume ~15.3 MJ/day [23]. The players in the present study consumed slightly higher protein (g/kg) and lower carbohydrate (g/kg), fat (g) and alcohol (g/kg) compared to earlier reports from elite AF players [10,31,32]. However, there were also a few notable differences between the experienced and inexperienced players during the season, with the inexperienced players having increased fat and lower protein intakes compared to the experienced group at the start of the season and less total protein consumption during the season. One possible explanation for the increased fat intake at the start of the season is that the younger athletes in the inexperienced group (i.e. first year players) may not yet have developed appropriate food intake choices as they had not undertaken the clubs nutrition education program (10/23 inexperienced players were in their first year). This program provides the players with specific information and guidance on appropriate food selection choices and diet behaviors. It was also notable that nutrient intakes (relative to body mass) were similar for the experienced and inexperienced groups from the mid-preseason test point onwards test period, which may be a result of the players nutrition education program, or the consequence of players eating many similar meals together as food was provided to the players following several training sessions each week throughout the training year.

Relatively few studies have examined the nutritional intakes of AF players and its influence on body composition and performance [31,32]. The present results showed similar proportion of energy intake from the various macronutrients (i.e. carbohydrates ~50%, protein ~18% and fat ~30%) to these previous studies. There were however a few differences in the within season changes in these macronutrient intakes between the experienced and inexperienced groups. Most notably, the end season protein intake was much lower than the previous measures in the season, but similar to other reports in AF [10]. Similarly, the large increase in alcohol intake at the end of season was likely explained by the traditional end of season recreational activities, which has been reported elsewhere [33]. In this study, the final measure was completed one week after the end of the competition season, and the players had ceased the season's training and commenced several days of post-season celebrations.

There are limitations with the design and implementation of the present study that must be acknowledged. Firstly, the results in this study are only taken from a single AF club and therefore the results of this study may be influenced by the specific training philosophy and player characteristics at this particular club. Whilst this study was conducted over just one single season, longitudinal research tracking player's physical development over multiple seasons could be implemented. The present findings are also limited to a narrow battery of strength tests to determine physical performance and future studies could adopt a more comprehensive range of both strength and power tests for both upper and lower body for a more thorough analysis of the relationships between training, nutrition and physical performance. Finally, limitations of a player recalling food intake will add to the inaccuracy of reporting nutrient intakes. Underreporting is a well-documented limitation of self-reported dietary records [34] and this has been shown to be more common amongst healthy eaters such as the present cohort [35]. Whilst this may have occurred, we have no indication of reporting bias in the present study and diet comparisons have been made to other studies using similar diet recall methodology.

In summary the main findings from this investigation were that FFSTM was significantly different between experienced and inexperience AF players, although %FFSTM was similar between groups. The difference in FFSTM is most likely reflective of the differences in training experience and possibly even maturation status. Players lost FM during the preseason and maintained this loss throughout the inseason phase. Upper body strength increased during the preseason and was maintained during the inseason. Changes in wholebody FFSTM and upper body FSTM were related to small changes in upper body strength performance. The energy and carbohydrate intakes of the players in this study were slightly lower than previous reports and slightly below current recommendations – and these may need to be increased for greater increases in FFSTM in both experienced and inexperienced players.

Practical Implications

The present findings provide new information showing relatively small increases in FFSTM, mostly during the preseason period in both experienced and inexperienced AF players. These changes in FFSTM were correlated with changes in upper body strength performance, highlighting the importance of optimising FFSTM in AF players. These findings have practical implications for support staff working to improve the physical capacities of professional AF players. Whilst physical development is not always the primary focus of training in AF, (i.e. developing skill, technical and tactical abilities usually take priority in a club's training program) coaches should be careful to ensure the appropriate balance in programming training and fuelling players according to each players goals is required to optimise physical qualities. The present results also suggest that specific focus should be paid to providing increased energy during periods of increased training, such as during the preseason or days that include multiple sessions per day. Particular focus should be on increasing total energy relative to changes in exercise energy expenditure and increasing carbohydrate intakes during periods of heavy training.

Coaches should also be aware that it can take >1 y to develop the appropriate levels of FFSTM in young players and take a long-term view when developing the physical and performance abilities of inexperienced players. Future studies on the longitudinal seasonal changes in body composition, nutrient intake and physical performance is require to understand the rate of development in inexperienced players. Specific information on the typical changes during the initial years after being recruited into the AFL would assist coaches and scientists better understand the factors that may influence long term physical development in younger AF players.

References

1. Coutts AJ, Kempton T, Sullivan C, Bilsborough J, Cordy J, Rampinini E. Metabolic power and energetic costs of professional Australian Football match-play. *J. Sci. Med. Sport.* 2014:in press.

2. Sullivan C, Bilsborough JC, Cianciosi M, Hocking J, Cordy J, Coutts AJ. Match score affects activity profile and skill performance in professional Australian Football players. *J. Sci. Med. Sport.* 2014;17:326-331.

3. Sullivan C, Bilsborough JC, Cianciosi M, Hocking J, Cordy JT, Coutts AJ. Factors affecting match performance in professional Australian football. *Int. J. Sports Physiol. Perf.* 2014;9(3):561-566.

4. Gastin PB, McLean O, Spittle M, Breed RV. Quantification of tackling demands in professional Australian football using integrated wearable athlete tracking technology. *J. Sci. Med. Sport.* 2013;16(6):589-593.

5. Veale JP, Pearce AJ, Buttifant D, Carlson JS. Anthropometric profiling of elite junior and senior Australian football players. *Int. J. Sports Physiol. Perf.* 2010;5:509-520.

6. Bilsborough JC, Greenway K, Opar D, et al. Comparison of anthropometry, upper body strength and lower body power characteristics in different levels of Australian Football players. *Journal of strength and conditioning research/National Strength & Conditioning Association.* 2014;29(3):826-834.

7. Young WB, Newton RU, Doyle TL, et al. Physiological and anthropometric characteristics of starters and non-starters and playing positions in elite Australian Rules Football: a case study. *J. Sci. Med. Sport.* 2005;8(3):333-345.

8. Hrysomallis C, Buttifant D. Influence of training years on upper-body strength and power changes during the competitive season for professional Australian rules football players. *J. Sci. Med. Sport.* 2012;15(4):374-378.

9. Bilsborough JC, Greenway K, Opar D, et al. Anthropometric, strength and power characteristics of Australian Football players. *J. Strength Cond. Res.* 2014:in press.

10. Ebert TR. Nutrition for the Australian Rules Football player. *J. Sci. Med. Sport.* 2000;3(4):369-382.

11. Harley JA, Hind K, O'Hara JP. Three-compartment body composition changes in elite rugby league players during a super league season, measured by dual-energy X-ray absorptiometry. *J. Strength Cond. Res.* 2011;25(4):1024-1029.

12. Carling C, Orhant E. Variation in body composition in professional soccer players: interseasonal and intraseasonal changes and the effects of exposure time and player position. *J. Strength Cond. Res.* 2010;24(5):1332-1339.

13. Egan E, Wallace J, Reilly T, Chantler P, Lawlor J. Body composition and bone mineral density changes during a Premier League season as measured by dual-energy x-ray absorptiometry. *Int. J. Body Comp. Res.* 2006;4(2):61-66.

14. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J. Strength Cond. Res.* 2013;27(1):270-276.

15. Santos DA, Gobbo LA, Matias CN, et al. Body composition in taller individuals using DXA: A validation study for athletic and non-athletic populations. *J. Sports Sci.* 2013;31(4):405-413.

16. Bilsborough JC, Greenway K, Opar D, Livingstone S, Cordy J, Coutts AJ. The accuracy and precision of DXA for assessing body composition in team sport athletes. *J. Sports Sci.* 2014;32(19):1821-1828.

17. Cameron ME, van Staveren WA. *Manual on methodology for food consumption studies* New York Oxford Medical Publications; 1988.

18. Burke LM, Gollan R, Read RSD. Seasonal changes in body composition in Australian Rules footballers. *Br. J. Sports Med.* 1986;20(2):69-71.

19. Argus CK, Gill N, Keogh J, Hopkins WG, Beaven CM. Effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional rugby union players. *J. Sports Sci.* 2010;28(6):679-686.

20. Silvestre R, Kraemer WJ, West C, et al. Body composition and physical performance during a National Collegiate Athletic Association Division I men's soccer season. *J. Strength Cond. Res.* 2006;20(4):962-970.

21. Walker EJ, McAinch AJ, Sweeting A, Aughey RJ. Inertial sensors to estimate the energy expenditure of team-sport athletes. *J Sci Med Sport.* 2015.

22. Mujika I, Burke LM. Nutrition in team sports. *Ann. Nutr. Metab.* 2010;57(suppl 2):26-35.

23. Holway FE, Spriet LL. Sport-specific nutrition: practical strategies for team sports. *J. Sports Sci.* 2011;29 Suppl 1:S115-125.

24. Clark M, Reed DB, Crouse SF, Armstrong RB. Pre- and post-season dietary intake, body composition, and performance indices of NCAA division I female soccer players. *Int. J. Sport Nutr. Exerc. Metab.* 2003;13(3):303-319.

25. Martin MK, Martin DT, Collier GR, Burke LM. Voluntary food intake by elite female cyclists during training and racing: influence of daily energy expenditure and body composition. *International Journal of Sports Nutrition and Exercise Metabolism.* 2002;12(3):239-267.

26. Phillips SM. Dietary protein for athletes: from requirements to metabolic advantage. *Appl. Physiol. Nutr. Metab.* 2006;31(6):647-654.

27. Areta JL, Burke LM, Camera DM, 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):E989-997.

28. Argus CK, Gill ND, Keogh JW, Hopkins WG, Beaven CM. Changes in strength, power, and steroid hormones during a professional rugby union competition. *J. Strength Cond. Res.* 2009;23(5):1583-1592.

29. Baker D. The effects of an in-season of concurrent training on the maintenance of maximal strength and power in professional and college-aged rugby league football players. *J. Strength Cond. Res.* 2001;15(2):172-177.

30. Hoffman JR, Kang J. Strength changes during an in-season resistance-training program for football. *J. Strength Cond. Res.* 2003;17(1):109-114.

31. Burke LM, Read R. A study of dietary patterns of elite Australian Football Players. *Can. J. Sport Sci.* 1988;13(1):15-19.

32. Schokman CP, Rutishauser IH, Wallace RJ. Pre- and postgame macronutrient intake of a group of elite Australian football players. *Int. J. Sport Nutr.* 1999;9(1):60-69.

33. Dietze PM, Fitzgerald JL, Jenkinson RA. Drinking by professional Australian Football League (AFL) players: prevalence and correlates of risk. *Med. J. Aust.* 2008;189(9):479-483.

34. Hill RJ, Davies PS. The validity of self-reported energy intake as determined using the doubly labelled water technique. *Br. J. Nutr.* 2001;85(4):415-430.

35. Scagliusi FB, Ferriolli E, Pfrimer K, et al. Under-reporting of energy intake is more prevalent in a healthy dietary pattern cluster. *Br. J. Nutr.* 2008;100(5):1060-1068.

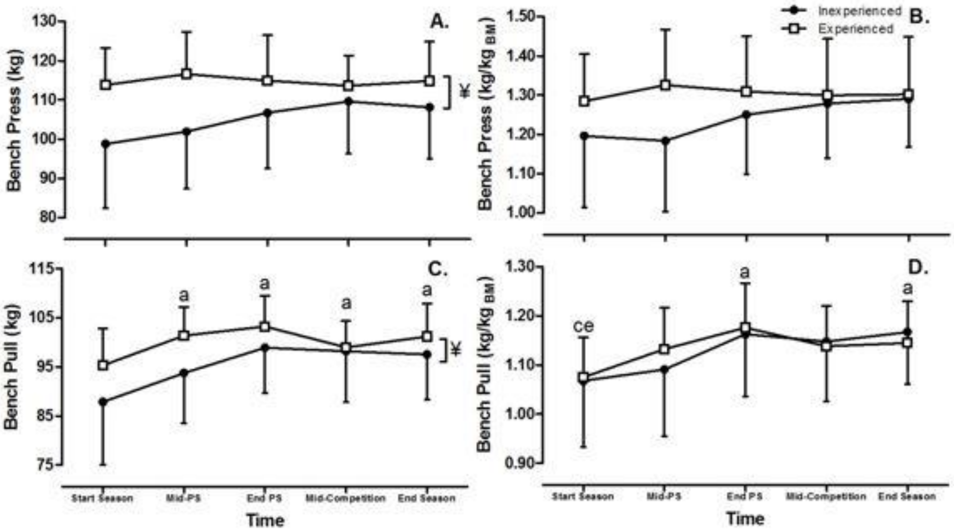

Figure 1. Seasonal changes in A) bench press, B) relative bench press, C) bench pull, and D) relative bench pull performance in experienced and inexperienced professional AF players (mean ±SD). [¥] - sig. main effects between groups, [a] - sig. different to Start of Preseason, [b] - sig. different to Mid-Preseason, [c] - sig different to End-Preseason, [d] – sig different to Mid-Competition, [e] - sig different to End Season, all P < 0.001.

"Changes in Anthropometry, Upper Body Strength and Nutrient Intake in Professional Australian Football Players During a Season" by Bilsborough JC et al.
International Journal of Sports Physiology and Performance

Table 1. Training descriptives for the experienced and inexperienced AF players during the different training phases of the season (mean ±SD).

	Start Preseason		Mid-Preseason		End Preseason		Mid-Competition		End Season		***P* value**	***P* value**
	Experienced	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Time**	**Experience**
Weekly Training TLs												
Session-RPE (AU)	3374 ± 1003[cde]	3680 ± 652*[cde]	3143 ± 1447[cde]	3437 ± 1566[cde]	2414 ± 620[abe]	2604 ± 627*[abe]	2417 ± 902[abe]	2511 ± 860*[abe]	1998 ± 701[abcd]	2174 ± 742*[abcd]	< 0.001	0.002
Week Duration (min)	437 ± 155[cde]	471 ± 129[cde]	444 ± 207[cde]	465 ± 211[cde]	304 ± 69[abde]	316 ± 63[abde]	277 ± 87[abce]	275 ± 86[abce]	234 ± 74[abcd]	240 ± 85[abcd]	< 0.001	0.103
Weekly RPE (1-10)	5.8 ± 0.6	5.5 ± 0.7	5.5 ± 0.7[c]	5.5 ± 0.7[c]	5.7 ± 0.6[e]	5.8 ± 0.6[e]	5.6 ± 0.7	5.6 ± 0.7	5.4 ± 0.7	5.7 ± 0.8	< 0.001	0.175
Resistance Tonnage (kg)	8724 ± 3270[bcde]	10985 ± 3656*[bcde]	7629 ± 5133[cde]	8810 ± 3413*[cde]	5124 ± 2694[e]	6247 ± 2971*[e]	4770 ± 3259[ab]	5272 ± 2618*[ab]	4395 ± 3094[abc]	4963 ± 2182*[abc]	< 0.001	<0.001
Resistance Tonnage U (kg)	6569 ± 2723[cde]	8405 ± 2249*[cde]	5526 ±3300[cde]	6578 ± 2594*[cde]	3907 ± 2278[ab]	4645 ±2461*[ab]	4079 ± 2908[ab]	4667 ± 2312*[ab]	3745 ± 2663[ab]	4300 ± 1913[ab]	< 0.001	<0.001
Resistance Tonnage LB (kg)	2696 ± 1661[bcde]	3233 ± 1778[bcde]	1954 ±1420[acde]	2219 ± 1177[acde]	1431 ± 1277[abde]	1768 ± 1426[abde]	940 ± 671[abc]	889 ± 513[abc]	772 ± 840[abc]	771 ± 585[abc]	< 0.001	0.060
Resistance TL (AU)	1324 ± 385[bcde]	1483 ± 281*[bcde]	915 ± 447[cde]	1109 ± 493*[cde]	644 ± 300[abe]	740 ± 280*[abe]	659 ± 419[abe]	702 ± 359*[abe]	469 ± 324[abcd]	569 ± 328*[abcd]	< 0.001	<0.001
Resistance TL UB (AU)	944 ± 367 [bcde]	1083 ± 298[cde]	704 ± 347[ace]	835 ± 382*[cde]	515 ± 263[ab]	573 ± 247[ab]	594 ± 351[ae]	653 ± 287[ab]	430 ± 261[abd]	551 ± 263*[ab]	< 0.001	<0.001
Resistance TL LB (AU)	382 ± 195[bcde]	396 ± 189[cde]	241 ± 135[acde]	296 ± 150[cde]	158 ± 100[abe]	192 ±92[abde]	139 ± 97[ab]	122 ± 63[abc]	90 ± 85[ab]	100 ± 74[abcd]	< 0.001	0.088

[*] - sig different to Experienced, [a] - sig. different to Start of Preseason, [b] - sig. different to Mid-Preseason, [c] - sig different to End-Preseason, [d] – sig different to Mid-Competition, [e] - sig different to End Season. UB – upper body, LB – lower body, TL – Training Load

Table 2: Seasonal changes in whole body and appendicular anthropometrical measures in experienced and inexperienced professional AF players (mean ±SD).

	Start Preseason		**Mid-Preseason**		**End Preseason**		**Mid-Competition**		**End Season**		***P Value***	***P Value***
	Experienced	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Time**	**Experience**
Whole Body												
BM (kg)	89.2 ± 7.1	84.2 ± 8.2*	89.3 ± 7.7	85.2 ± 7.9*	88.2 ± 7.9	85.5 ± 7.8*	88.1 ± 7.7	85.7 ± 8.5*	87.9 ± 7.6	85.2 ± 8.1*	0.996	0.001
FM (g)	9401 ± 2711	8256 ± 2727	8073 ± 2004	7316 ± 2062	7160 ± 1596[a]	6779 ± 1987[a]	7044 ± 1596[a]	7172 ± 2445[a]	6918 ± 1689[a]	7234 ± 2187[a]	<0.001	0.19
FFSTM (g)	74993 ± 5423	71230 ± 6759*	76836 ± 6445	73304 ± 6779*	75991 ± 6465	73938 ± 6539*	76142 ± 6437	74156 ± 6778*	75828 ± 6526	73284 ± 6476*	0.527	0.001
BMC (g)	4405 ± 430	4174 ± 394*	4466 ± 424	4204 ± 399*	4485 ± 451	4252 ± 412*	4493 ± 455	4276 ± 408*	4527 ± 479	4271 ± 413*	0.745	<0001
FFSTM (%)	84.5 ± 2.6	85.2 ± 2.5	86.0 ± 1.8[a]	86.4 ± 2.2[a]	86.7 ± 1.4[a]	87.1 ± 1.8[a]	86.9 ± 1.5[a]	86.7 ± 2.1[a]	86.9 ± 1.8[a]	86.5 ± 1.8[a]	<0.001	0.049
FM (%)	10.5 ± 2.7	9.8 ± 2.7	9.0 ± 1.9[a]	8.6 ± 2.3[a]	8.1 ± 1.4[a]	7.9 ± 1.9[a]	8.0 ± 1.5[a]	8.3 ± 2.3[a]	7.9 ± 1.8[a]	8.4 ± 1.9[a]	<0.001	0.692
Trunk												
FM (g)	4684 ± 1276	4063 ± 1285	3704.8 ± 997[a]	3363 ± 1029[a]	3540 ± 808[a]	3181 ± 877[a]	3569 ± 765[a]	3539 ± 1146[a]	3609 ±911[a]	3616 ± 1000[a]	<0.001	0.471
FFSTM (g)	35078 ±2804	33147 ± 3468	36903 ± 3161[a]	34904±3283[a]	36261 ± 3096	34527 ± 3059	36329 ± 3909[a]	34841 ± 3176[a]	35199 ±3325[b]	33855 ± 3190[b]	0.046	<0.001
BMC (g)	1524 ± 168	1453 ± 159*	1591 ± 177	1482 ± 147*	1613 ±192	1493 ± 152*	1624± 188[a]	1512 ± 143*[a]	1620 ± 197	1493 ± 158*	0.189	<0.001
FFSTM (%)	85.0 ± 2.8	85.8 ± 2.8	87.4 ± 2.0[a]	87.8 ± 2.4[a]	87.6 ± 1.6[a]	88.1 ± 1.8[a]	87.5 ± 1.7[a]	87.4 ± 2.2[a]	87.0 ± 2.2[a]	87.0 ±1.9[a]	<0.001	0.296
FM (%)	11.3 ± 2.9	10.5 ± 3.0	8.8 ± 2.2[a]	8.5 ± 2.5[a]	8.5 ± 1.6[a]	8.1 ± 1.9[a]	8.6 ± 1.7[a]	8.8 ± 2.3[a]	9.0 ± 2.3[a]	9.2 ± 1.9[a]	<0.001	0.436
Arms												
FM (g)	810 ± 289	678 ± 226*	762 ± 207	695 ± 148*	628 ± 148[ab]	583 ± 138*[ab]	591 ± 155[ab]	587 ± 191*[ab]	559 ± 140[ab]	556 ± 140*[ab]	<0.001	0.041
FFSTM (g)	9445 ± 890	8603 ± 983*	9359 ± 915	8807 ± 953*	9310 ± 1004	8930 ± 923*	9278 ± 944	8880 ± 1022*	9351 ± 921	8994 ± 967*	0.961	<0.001
BMC (g)	592 ±71	526 ± 61*	580 ± 66	531 ± 61*	587 ± 67	540 ± 63*	588 ± 68	540 ± 66*	595 ± 70.3	549 ± 62*	0.800	<0.001
FFSTM (%)	87.2 ± 2.2	87.8 ± 1.6	87.5 ± 1.5	87.8 ± 1.3	88.5 ± 1.0[a]	88.9 ± 1.1[a]	88.7 ± 1.2[a]	88.8 ± 1.2[a]	89.0 ± 1.0[a]	89.1 ± 1.0[a]	<0.001	0.119
FM (%)	7.4 ± 2.1	6.8 ± 1.7	7.1 ± 1.5	6.9 ± 1.3	5.9 ± 1.0[a]	5.8 ± 1.0[a]	5.6 ± 1.1[a]	5.8 ± 1.3[a]	5.3 ± 1.0[a]	5.5 ± 0.9[a]	<0.001	0.522
Legs												

	Start Preseason		**Mid-Preseason**		**End Preseason**		**Mid-Competition**		**End Season**		***P* Value**	***P* Value**
	Experienced	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**	**Time**	**Experience**
FM (g)	3481 ± 1342	3104 ± 1246	3142 ± 962	2831 ± 946	2612 ± 823[a]	2609 ± 942[a]	2539 ± 815[a]	2679 ± 1031[a]	2447 ± 811[a]	2735 ± 983[a]	0.002	0.691
FFSTM (g)	26357 ± 2230	25314 ± 2840*	26536 ± 2607	25468 ± 3117*	26381 ± 2860	26404 ± 2874*	2104 ± 421	26213 ± 2983*	27078 ± 2678	26234 ± 2744*	0.618	0.082
BMC (g)	1753 ± 215	1661± 195*	1753 ±210	1658 ± 191*	1747 ± 212	1685 ± 197*	1749 ± 2123	1684 ± 198*	1763 ± 219	1689 ± 194*	0.989	0.005
FFSTM (%)	83.6 ± 3.5	84.3 ± 3.3	84.5 ± 2.3	85.0 ± 2.9	85.9 ± 2.0[a]	86.1 ±2.4[a]	86.1 ± 2.2[a]	85.8 ± 2.7[a]	86.6 ± 2.2[a]	85.7 ± 2.3[a]	0.929	0.929
FM (%)	10.8 ± 3.4	10.2 ± 3.4	9.9 ± 2.3	9.4 ± 2.9	8.4 ± 2.0[a]	8.4 ± 2.5[a]	8.2 ± 2.1[a]	8.7 ± 2.8[a]	7.7 ± 2.1[a]	8.8 ± 2.4[a]	<0.001	0.829

* - sig different to Experienced, [a] - sig. different to Start of Preseason, [b] - sig. different to Mid-Preseason, [c] - sig different to End-Preseason, [d] – sig different to Mid-Competition, [e] - sig different to End Season.

Table 3. Seasonal changes in energy and nutrient intake in experienced and inexperienced professional Australian Football players (mean ±SD).

	Start Preseason		**Mid-Preseason**		**End Preseason**		**Mid-Competition**		**End Season**		***P Value***	***P Value***
	Experienced	**Inexperienced**	**Experienced**	**Inexperienced**	**Experienced**	**Inexperienced**			**Experienced**	**Inexperienced**	**Time**	**Experience**
Energy (kJ/day)	13106 ± 2230	12663 ± 4427	11804 ± 4481	11058 ± 367	12359 ± 2916	11895 ± 3903	-	-	13752 ± 8407	13450 ± 9167	0.265	0.557
Protein (g/day)	190 ± 64[e]	174 ± 77*[e]	182 ± 77[e]	150 ± 73*[e]	215 ± 60[e]	156 ± 55*[e]	-	-	135 ± 78	118 ± 67*	<0.001	0.037
Carbohydrate (g/day)	379 ± 66	321 ± 142	368 ± 163	353 ± 99	354 ± 114	368 ± 142	-	-	339 ± 180	363 ± 224	0.989	0.644
Fat Total (g/day)	86 ± 25	110 ± 40	61 ± 29[a]	63 ± 39[a]	65 ± 31[a]	75 ± 24[a]	-	-	76 ± 43	76 ± 65	<0.001	0.111
Water (ml/day)	3642± 1543	3212 ± 955	3626 ± 1322	3027 ± 1313	3199 ± 1355	2659 ± 750	-	-	4215 ± 3971[c]	4509 ± 2820[c]	0.009	0.315
Protein (%)	25.3 ± 5.3	23.2 ± 4.8*	26.0 ± 7.6	22.5 ± 6.4	29.9 ± 6.2	22.8 ± 6.2	-	-	19.4 ± 9.5[abc]	18.4 ± 8.7[abc]	<0.001	0.002
Carbohydrate (%)	49.1 ± 7.0	43.6 ± 8.7	50.3 ± 9.4[e]	52.2 ± 9.3[e]	47.0 ± 10.2	49.9 ± 6.8	-	-	40.2 ± 17.0	44.5 ± 16.0	0.003	0.594
Fat (%)	25.6 ± 5.6[bce]	33.1 ± 6.7*[bce]	19.0 ± 5.0	19.9 ± 7.6	19.6 ± 7.2	23.5 ± 5.6	-	-	22.7 ± 10.9	21.3 ± 9.4	<0.001	0.022
Alcohol (%)	0	0	0.2 ± 0.8	0	0	0	-	-	12.3 ± 20.0[abc]	11.9 ± 16.9	<0.001	0.918
Energy (kJ/kg)	147 ± 27	154 ± 54	130 ± 42	131 ± 44	141 ± 32	140 ± 46	-	-	155 ± 89[a]	159 ± 109[a]	0.186	0.781
Protein (g/kg)	2.1 ± 0.7[e]	2.1 ± 1.0*[e]	2.0 ± 0.8[e]	1.8 ± 0.9[e]	2.4 ± 0.7[e]	1.8 ± 0.6[e]	-	-	1.5 ± 0.8	1.4 ± 0.8	<0.001	0.035
Carbohydrate (g/kg)	4.3 ± 0.8	3.9 ± 1.6	4.1 ± 1.6	4.2 ± 1.2	4.0 ± 1.2	4.3 ± 1.7	-	-	3.8 ± 2.0	4.3 ± 2.7	0.989	0.644
Fat (g/kg)	1.0 ± 0.3	1.4 ± 0.5*	0.7 ± 0.3[a]	0.8 ± 0.5[a]	0.7 ± 0.4[a]	0.9 ± 0.3[a]	-	-	0.8 ± 0.4	0.9 ± 0.8	<0.001	0.013
Alcohol (g/kg)	0	0	0	0.68± 3.4	0	0	-	-	82.6±122.4[abc]	97.5±185.3[abc]	<0.001	0.918

[*] - sig different to Experienced, [a] - sig. different to Start of Preseason, [b] - sig. different to Mid-Preseason, [c] - sig different to End-Preseason, [d] - sig different to Mid-Competition, [e] - sig different to End Season