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## ORIGINAL INVESTIGATION

# DXA-derived estimates of energy balance and its relationship with changes in body composition across a season in team sport athletes

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## Abstract

This study examined the relationship between dual-energy x-ray absorptiometry (DXA)-derived estimates of energy balance (EB) and changes in body composition across various seasonal phases in team sport athletes. Forty-five Australian rules footballers underwent six DXA scans across a 12-month period (off-season [OS, Week 0–13], early [PS1, Week 13–22] and late pre-season [PS2, Week 22–31] and early [IS1, Week 3–42] and late in-season [IS2, Week 42–51]). EB (kcal·day<sup>-1</sup>) was estimated from changes in fat free soft tissue mass (FFSTM) and fat mass (FM) between scans according to a validated formula. An EB threshold of  $\pm 123$  kcal·day<sup>-1</sup> for >60 days demonstrated a *very likely* (>95% probability) change in FFSTM (>1.0 kg) and FM (>0.7 kg). There were small to almost perfect relationships between EB and changes in FM ( $r = 0.97$ , 95% CI, 0.96–0.98), FFSTM ( $r = -0.41$ ,  $-0.92$  to  $-0.52$ ) and body mass ( $r = 0.27$ , 0.14–0.40). EB was lowest during PS1 compared to all other phases (range,  $-265$  to  $-142$  kcal·day<sup>-1</sup>), with no other changes at any time. Increases in FFSTM were higher during OS compared to PS2 ( $1.6 \pm 0.4$  kg), and higher during PS1 compared to PS2, IS1, and IS2 (range, 1.6–2.1 kg). There were no changes during in-season ( $-0.1$ – $0.05$  kg). FM decreased only in PS1 compared to all other seasonal phases ( $-1.8$  to  $-1.0$  kg). Assessments of body composition can be used as a tool to estimate EB, which practically can be used to indicate athlete's training and nutrition behaviours/practices.

**Keywords:** AFL, training, nutrition, periodization, education

## Introduction

To obtain information about an athlete's energy balance (EB), practitioners assess energy intake and/or energy expenditure. Energy intake is often estimated via 3–7 day dietary recall, however, this method often under- and/or misreports energy intake (Capling et al., 2017). Comparatively, measurement of energy expenditure by wearable technology (Buchheit, Manouvrier, Cassirame, & Morin, 2015) and the doubly-labelled water technique, (Anderson et al., 2017) also has challenges, owing to varying degrees of validity, reliability, logistics and expense. Additionally, quantifying both intake

and expenditure of energy places a large burden on athletes (Burke, Lundy, Fahrenholtz, & Melin, 2018). Whilst team sport athletes undertake a range of training modalities within a training week, the specific macronutrient and caloric requirement and rate of substrate utilization inherent to each individual mode is unknown. As such, if information relating to the overall EB (obtained by other methods) of athletes across different times in a season were available (independent of specifically knowing energy intake and expenditure), then more accurate implementation of training, nutrition and education programmes to optimize body composition may be possible.

Body composition of athletes is routinely assessed by practitioners via dual x-ray absorptiometry (DXA). DXA provides estimates of muscle mass, via the measurement of fat free soft tissue mass (FFSTM), fat mass (FM) and bone mass, as both an overall total and individual regional body sites. In relation to EB, previous studies have used the changes in DXA between two time points to determine energy balance. Indeed, by using the established metabolizable energy densities necessary for a change in total body FFSTM ( $1.0 \text{ kcal.g}^{-1}$ ) and FM ( $9.5 \text{ kcal.g}^{-1}$ ) to occur (Dulloo & Jacquet, 1999), and as EB is computed as the function of time between scans, EB can be estimated for a given period of time. This method of determining EB has previously been validated (de Jonge et al., 2007; Pieper et al., 2011) and has been used to calculate EB in athletes and military personnel. For example, Fortes et al. (2011) demonstrated that a modest energy deficit ( $2.2 \text{ MJ.day}^{-1}$ ), calculated from DXA-derived estimates of FFSTM and FM, evoked negative effects on body composition and physical performance. Recently, Murphy, Carrigan, Philip Karl, Pasiakos, and Margolis (2018) reported that a greater total negative EB (combination of duration and magnitude of EB) equates to greater declines in lower-body power and strength. Together, this indicates that this approach may be useful in determining EB in athletes. Further, as the acute assessment (3–7 days) of energy intake and expenditure may not represent longer-term states of EB, such as those associated with team sport seasonal training plans, this previously used approach may negate numerous methodological issues.

To date, there has only been one study that has examined EB of athletes across a season using DXA-derived estimates of FM and FFSTM (Silva et al., 2017). In this study, the authors reported in 80 athletes, from the start of the training season to the mid-point of competition, a small but significant negative EB ( $17.4 \pm 72.7 \text{ kcal.day}^{-1}$ ), which varied widely between sports and gender. Despite this, no research has examined fluctuations in EB across different phases of a season in a team sport environment. Given that training and competition loads differ between pre-season and in-season phases in team sports, (Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2016) it is therefore logical that changes in EB and body composition also vary in accordance with specific times of a season. This information may be particularly useful for practitioners when educating athletes and periodizing training and nutrition plans. Accordingly, the aim of the current study was to quantify DXA-derived estimates of EB and determine its relationship with changes in body composition across various phases of a season in team sport athletes.

## Methods

### Subjects

Forty-five professional AF athletes (age:  $22.9 \pm 3.7$  yr, height:  $185 \pm 29$  cm, body mass:  $86.8 \pm 9.7$  kg) from the same Australian rules football club participated in the study. The participating athletes competed in the Australian Football League (AFL), or when not selected, the North East Australian Football League (NEAFL). Ethical clearance was obtained from Griffith University Human Research Ethics Committee, and the Declaration of Helsinki was adhered to.

### Design

Changes in body composition and EB were assessed across a 12-month period. DXA scans were performed six times, entailing an off season, pre-season and in-season. These timeframes allowed for subsequent calculation of changes in FFSTM, FM, body mass (BM), and EB for each phase of the season. Each phase was categorized as;

- Off season (OS) – August 2017 (week 0) – November 2017 (week 13),  $89 \pm 8$  days;
- Pre-season 1 (PS1) – November 2017 – January 2018 (week 22),  $67 \pm 12$  days;
- Pre-season 2 (PS2) – January 2018 – March 2018 (week 31),  $60 \pm 5$  days;
- In-season 1 (IS1) – March 2018 – June 2018 (week 42),  $80 \pm 4$  days;
- In-season 2 (IS2) – June 2018 – August 2018 (week 51),  $60 \pm 3$  days.

Comparable pre-season and in-season phases have been characterized previously in relation to training and competition loads (Juhari et al., 2018; Ritchie et al., 2016). The athletes followed a training programme that was designed by the club's strength and conditioning staff. The OS period consisted of individualized training plans consisting of ~6 resistance and 3 running sessions per week, whilst PS1 consisted of 4–6 resistance, 3–4 field-based sessions (consisting of both sport-specific skills training and running conditioning), 2–3 cross-training sessions (boxing, cycling, swimming), and 1–2 injury prevention sessions. PS1 incorporated a 2-week Christmas break, whereby a light training programme was administered. During PS2, training was more specific to competition preparation, where resistance training reduced to 3–4 sessions per week, cross-training reduced to 1–2 sessions per week, and the weekly duration of the 3–4 field-based sessions increased.

During IS1 and IS2, the athletes competed in one competitive match per week (total of 22 matches). Each week comprised of 2–3 field, and 2–3 resistance

sessions per week. Cross-training was limited during the in-season, although was included where necessary (i.e. rehab). As there is no standard measure of work done for the different training modalities, an approximation of duration for each mode, as a proxy, across different phases of a season can be seen previously (Juhari et al., 2018). Pitch-based sessions preceded resistance training.

During PS and IS the athletes were provided with lunch post-training as buffet style and snacks ad libitum, within the confines of the training environment. Menus were determined by the club's nutritionist and dictated by the needs of the group and the daily training demands; each athlete had their own nutritional goals. When the team stayed in a hotel for competition, the club's nutritionist provided a menu to the hotel, which typically covered the day before a game, day of the game and immediately post game. Generally, all menus consisted of two varying sources of carbohydrate and protein options, permitting the athletes to meet their nutritional goals. Protein was portion controlled to provide  $\sim 0.35 \text{ g.kg.BM}^{-1}$  per athlete.

#### Body composition assessment

All body composition assessments were conducted within a 30 min period. BM was assessed to the nearest 0.01 kg with digital scales (Seca, Hamberg, Germany). As per previous research in team sport athletes, (Bilsborough, Greenway, Livingston, Cordy, & Coutts, 2016) DXA (Medilink Medix DR, 2D-Fan beam, Montpellier, France) was used to estimate FFSTM and FM. Note that depending on the context, lean muscle mass and FFSTM are used interchangeably throughout the remainder of the manuscript. For each scan, procedures were standardized in accordance with best practice, (Nana et al., 2016) where the same technician conducted and analyzed all scans to reduce variability. Athletes wore limited clothing, the same pair of shorts, and all jewellery was removed. Due to the slightly different scan times ( $\pm 90 \text{ min}$ ) across the season (due to practical and logistical reasons), athletes had to be bladder void and in a euhydrated state, assessed by urine specific gravity ( $< 1.020$ ) (Oppliger & Bartok, 2002). It is recommended that no training activity precedes any DXA scan, however, in team sports with squads of 45 players, scheduling clashes may occur. That said, 16 of the 202 scans (due to scheduling clashes) took place following short duration ( $< 20 \text{ min}$ ) stationary injury prevention/rehabilitation gym work. Given that only whole body estimates were used, and that a 62 min strength session has little influence on DXA-derived estimates of total FFSTM and FM, (Nana,

Slater, Hopkins, & Burke, 2013) it was assumed that the stationary work preceding the 16 scans would not affect the scan results in the current study. Furthermore, this study only considered a change 'real' if the mean difference between scans of FFSTM and FM changes exceeded the variance (calculated as 2 x the between-subject standard deviation), and if the likelihood exceeded 95% (*very likely*) (see below for detail).

#### DXA reliability

Within-subject between-day test-retest reliability for total FM and FFSTM was conducted on 15 different professional team sport athletes (height:  $182 \pm 7 \text{ cm}$ ; body mass:  $70.3 \pm 6.3 \text{ kg}$ ). Participants were scanned twice using the same 2D-Fan Beam DXA machine separated by 21-days using procedures and criteria consistent with the current study. For FFSTM (kg),  $\Delta \text{mean} \pm 90\% \text{ CI}$  was  $0.28 (-0.18 - 0.74)$ ,  $\text{TEM } x/\div 90\% \text{ CI}$  was  $0.71 (0.55 - 1.04)$  and  $\text{ICC} \pm 90\% \text{ CI}$  was  $0.98 (0.96 - 0.99)$ . For FM (kg),  $\Delta \text{mean} \pm 90\% \text{ CI}$  was  $0.27 (0.08 - 0.46)$ ,  $\text{TEM } x/\div 90\% \text{ CI}$  was  $0.29 (0.23 - 0.43)$  and  $\text{ICC} \pm 90\% \text{ CI}$  was  $0.96 (0.95 - 0.99)$ . These levels of reliability are comparable to that previously measured in athletes using Fan-Beam DXA (Bilsborough et al., 2014; Nana et al., 2013).

#### Estimation of energy balance

EB, expressed in kilocalories per day ( $\text{kcal} \cdot \text{day}^{-1}$ ) was estimated from absolute changes in FFSTM and FM between DXA scans. Consistent with previous research that has estimated EB in athletes (Silva et al., 2017) from DXA, using the known metabolizable energy densities to achieve a change in body energy stores of  $1.0 \text{ kcal g}^{-1}$  for FFSTM and  $9.5 \text{ kcal g}^{-1}$  for FM, (Dulloo & Jacquet, 1999) EB was calculated according to a previously validated equation: (de Jonge et al., 2007; Pieper et al., 2011)

$$\text{EB}(\text{kcal} \cdot \text{day}^{-1}) = 1.0 \frac{\Delta \text{FFSTM}}{\Delta t} + 9.5 \frac{\Delta \text{FM}}{\Delta t}$$

where EB is energy balance,  $\Delta \text{FFSTM}$  and  $\Delta \text{FM}$  are changes in grams of FFSTM and FM from scan to scan, and  $\Delta t$  is the number of days in between scans.

#### Statistical analysis

To determine whether relationships existed between EB and changes in body composition (FFSTM, FM and BM), Pearson's correlation coefficient ( $r$ ) was conducted for each phase of the season. If data

was determined as not normally distributed (via Kolmogorov–Smirnov), then non-parametric tests of Spearman’s rank correlation were performed. The following criteria were followed to interpret the magnitude of correlations: <0.1 trivial; 0.1–0.3 small; 0.3–0.5 moderate; 0.5–0.7 large; 0.7–0.9 very large; and 0.9–1.0 almost perfect, with 95% confidence intervals (CI) reported (Hopkins, 2002). To determine relationships between body composition (FFSTM, FM, BM) and EB between each phase of the season, linear mixed models were used. The body composition measure was included as the outcome, and phase was included as a fixed effect. Player identification was included as a random effect, as individual variability was accounted for using the random intercept and slope design. The least mean squares test provided pairwise comparisons between each phase. Differences were further assessed using standardized effect sizes and 95%  $\pm$  CI, categorized using the thresholds of; <0.2 trivial, 0.21–0.60 small, 0.61–1.20 moderate, 1.21–2.0 large and >2.0 very large (Hopkins, Marshall, Batterham, & Hanin, 2009). A magnitude-based approach was used, where effects were considered real if the likelihood of the effect being greater than 0.20 were described as: 75% to <95%, *likely*; 95% to <99.5%, *very likely*; >99.5%, *most likely* (Hopkins et al., 2009). Considering that interpretation of DXA changes vary based on different scan protocols (Nana et al., 2016) and to prevent over interpretation of our data (i.e. there is no clearly defined threshold or published data determining what a meaningful energy deficit or surplus is for a period >60 days that elicits changes in body composition), a conservative, but practical approach to determine ‘real’ changes was chosen. As such, differences in EB and body composition were determined when the mean difference between scans exceeded the variance (calculated as 2 x the between-subject standard deviation), and if the likelihood exceeded 95% (*very likely*). Data for each phase is presented as box and whisker plots, representing the median and interquartile range. Individual participant data points are included.

## Results

Relationships between EB and changes in FFSTM, FM and BM across the whole season and for each phase of the season can be seen in Figure 1 and Table I, respectively.

Figure 2 shows the between season phase comparisons for changes in EB, FFSTM, FM, and BM. The variance of change in BM across the season was 1.2 kg, FM 0.7 kg, FFSTM 1.0 kg and EB 123 kcal·day<sup>-1</sup>.

EB during PS1 was lower than OS (mean difference, 95% CI; -239, -430 to -49 kcal·day<sup>-1</sup>; ES;  $\pm$  95% CI,  $1.2 \pm 0.6$ ) PS2 (-265, -377 to -153 kcal·day<sup>-1</sup>;  $1.4 \pm 0.7$ ), IS1 (-209, -317 to -102 kcal·day<sup>-1</sup>;  $1.2 \pm 0.6$ ), and IS2 (-142, -246 to -38 kcal·day<sup>-1</sup>;  $0.8 \pm 0.4$ ). Further, EB during PS2

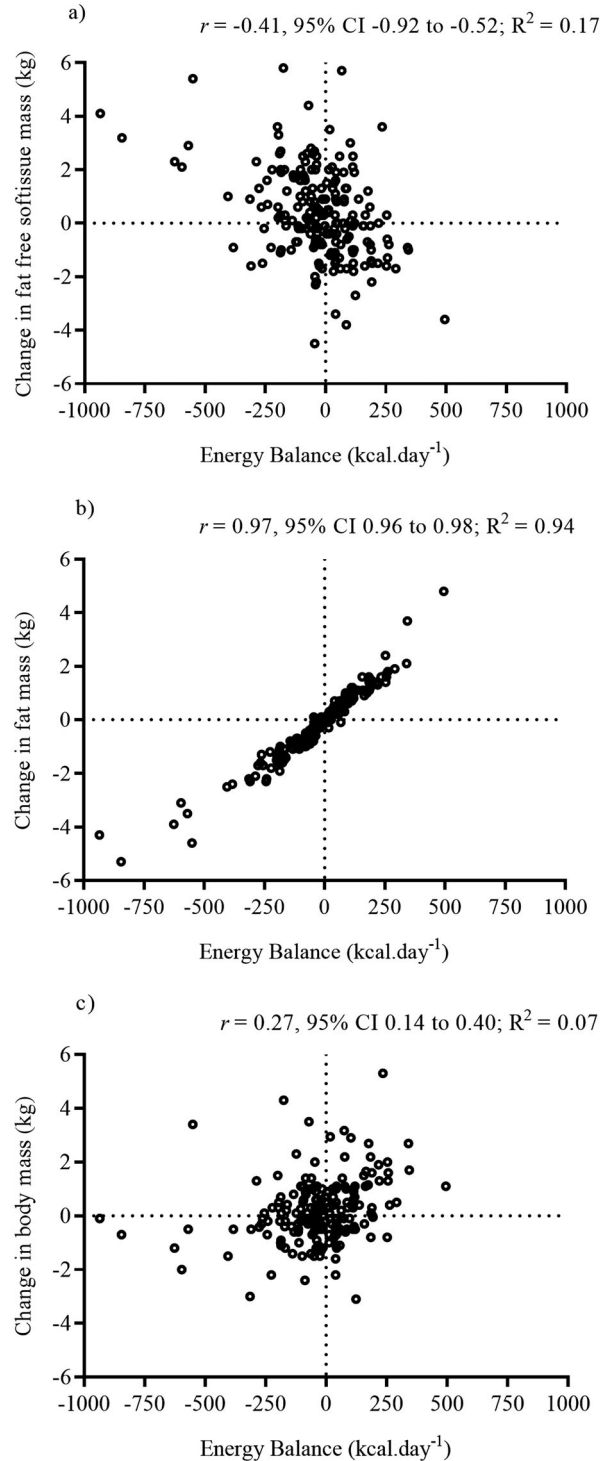


Figure 1. Relationships between EB and a) FFSTM, b) FM, and c) BM, pooled across the season for all athletes.

Table I. Pearson correlation coefficients ( $r$ )  $\pm$  95% CI for each season phase for FFSTM vs. EB, FM vs. EB and BM vs. EB. Due to PS1 FM and BM not normally distributed, spearman rank correlation was computed for this phase only, meaning there is no  $R^2$  for this phase.

Phase	FFSTM vs. EB				FM vs. EB				BM vs. EB			
	$R^2$	$r$	95% CI	Likelihood	$R^2$	$r$	95% CI	Likelihood	$R^2$	$r$	95% CI	Likelihood
OS ( $N=24$ )	0.27	-0.52	-0.76 to -0.15	<i>Very likely</i>	0.99	0.99	0.98–0.99	<i>Most likely</i>	0.25	0.50	0.13–0.75	<i>Very likely</i>
PS1 ( $N=45$ )		-0.21	-0.48–0.10	<i>Likely</i>		0.97	0.95–0.98	<i>Most likely</i>		0.30	0.01–0.55	<i>Likely</i>
PS2 ( $N=45$ )	0.05	-0.22	-0.48–0.08	<i>Likely</i>	0.98	0.99	0.98–0.99	<i>Most likely</i>	0.35	0.59	0.36–0.75	<i>Most likely</i>
IS1 ( $N=44$ )	0.01	-0.12	-0.40–0.19	<i>Possibly</i>	0.95	0.98	0.96–0.99	<i>Most likely</i>	0.01	0.11	-0.20–0.39	<i>Possibly</i>
IS2 ( $N=44$ )	0.12	-0.35	-0.59 to -0.05	<i>Very likely</i>	0.98	0.99	0.98–0.99	<i>Most likely</i>	0.00	0.05	-0.26–0.35	<i>Possibly</i>

FFSTM; fat free soft tissue mass, FM; fat mass, BM; body mass, EB; energy balance, OS; Off season, PS1; Pre-season 1, PS2; Pre-season 2, IS1; In season 1, IS2; In season 2. CI; confidence interval

was higher than IS2 (123, 48–199 kcal·day<sup>-1</sup>;  $0.9 \pm 0.6$ ). EB was similar between IS1 and IS2 (68, -8–144 kcal·day<sup>-1</sup>;  $0.7 \pm 1.2$ ).

Increases in FFSTM were higher during OS (mean difference, 95% CI; 1.5, 0.6–2.5 kg; ES;  $\pm$  95% CI,  $1.1 \pm 0.6$ ) and PS1 (2.1, 1.0–3.1 kg;  $1.3 \pm 0.7$ ) compared to PS2. Similarly, increases in FFSTM during PS1 were also higher than IS1 (1.7, 0.7–2.6 kg;  $1.1 \pm 0.4$ ) and IS2 (1.6, 0.6–2.6 kg;  $1.0 \pm 0.4$ ). Changes in FFSTM between PS2 and IS1 (0.4, 0.4–1.3;  $0.3 \pm 1.4$ ), PS2 and IS2 (0.5, 0.2–1.2;  $0.4 \pm 1.3$ ), and IS1 and IS2 (-0.1, -1.1–0.9 kg;  $0.1 \pm 0.6$ ) were negligible.

There were decreases in FM during PS1 compared to OS (mean difference, 95% CI; -1.6, 0.1–3.1 kg; ES;  $\pm$  95% CI,  $1.1 \pm 0.5$ ), PS2 (-1.8, 1.2–2.5 kg;  $1.6 \pm 0.8$ ), IS1 (-1.5, 0.8–2.2 kg;  $1.4 \pm 0.7$ ), and IS2 (-1.0, 0.4–1.7 kg;  $0.9 \pm 0.5$ ). FM increased more during PS2 compared to IS2 (0.8, 0.3–1.3 kg;  $0.9 \pm 0.6$ ), whilst there was no difference between in season phases (0.5, -0.1–1.1 kg;  $0.6 \pm 1.0$ ).

Changes in BM did not exceed the variance at any time during the season. Practically, however, there were increases during OS compared to IS1 (mean difference, 95% CI; 1.0, 0.1–1.9 kg; ES;  $\pm$  95% CI,  $0.9 \pm 0.5$ ) and IS2 (1.0, 0.1–2.0 kg;  $1.0 \pm 0.5$ ), with no other observable changes in BM between pre-season and in-season phases.

## Discussion

The aim of the current study was to quantify DXA-derived estimates of EB and determine its relationship with changes in body composition across various phases of a season in team sport athletes. As expected, we demonstrate that greater losses in FM are achieved when in a state of greater energy

deficit. However, these data demonstrated that increases in FFSTM are less dependent on EB status and can be achieved whilst in a negative EB. Specific to season phase, EB is lowest during early pre-season, FFSTM increased the most during off-season and early pre-season, whilst greater decreases in FM occur during early pre-season. In-season, athletes are in EB and there are no changes in body composition. Together, these data suggest that changes in EB and body composition may be periodized towards specific season phases, with the method of estimating EB from DXA changes representing a useful and viable educational tool for practitioners working with team sport athletes.

The assessment of EB of team sport athletes across a given period of time has received limited attention. In the current study, by obtaining multiple DXA scans, EB was able to be determined according to the change in body energy stores (i.e. FM and FFSTM) between two time points across varying seasonal timeframes. This means that the level of variance could also be identified permitting greater confidence in what a ‘real’ change was. Indeed, we identified that an energy deficit or surplus of 123 kcal·day<sup>-1</sup> is required to result in a *very likely* (i.e. >95% probability) change in body composition. This threshold is much larger compared to a recent report in individual pursuit and team sport athletes where a small energy deficit of  $17.4 \pm 72.7$  kcal·day<sup>-1</sup> (obtained from two DXA scans; one in pre-season and one in competition) was reported (Silva et al., 2017). The discrepancy in results between these studies could be explained by the methods used to determine a change in EB, the differing energy demands of the sports, and the number of scans used in the studies.

Whilst the optimal body composition of a team sport athlete remains unclear (and is likely sport-

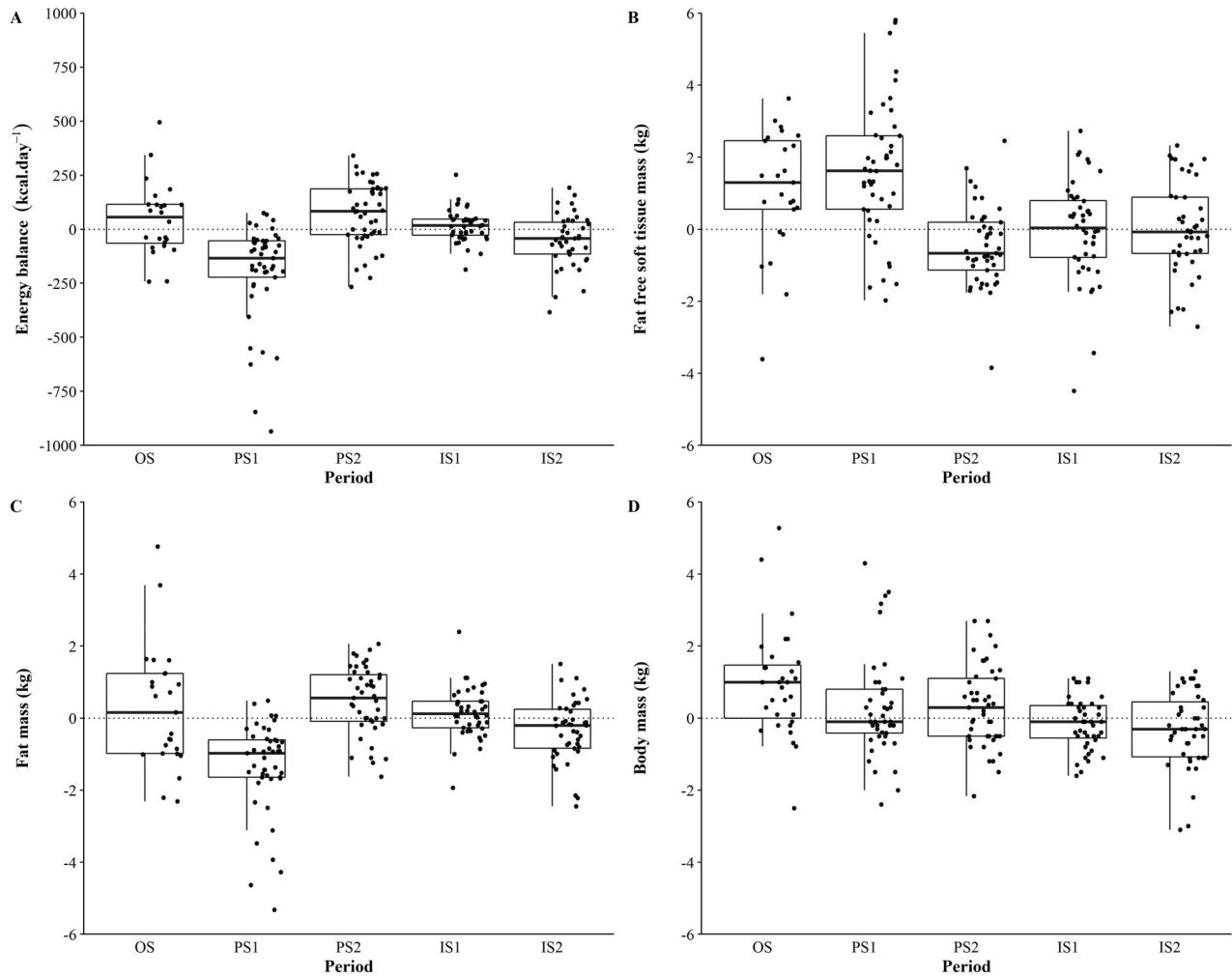


Figure 2. Box and whisker plot demonstrating the change in a) EB, b) FFSTM, c) FM, and d) BM for each season phase in order of occurrence. Data is shown as individual data points, median  $\pm$  interquartile range (IQR) and error bars are IQR \* 1.5.

and position-specific), by assessing changes in FM, FFSTM and EB over time, and how they fluctuate between different phases of a season may help in the process of optimizing body composition. The current study demonstrates that EB (as well as FM and FFSTM) varies across a season. For example, early pre-season (PS1) displayed an energy deficit of  $\sim 200 + \text{kcal}\cdot\text{day}^{-1}$  when compared to OS, PS2, IS1 and IS2, whilst during PS2 and IS1 and IS2 (a time whereby there is an increased focus on game plan development, technical and tactical training and recovery), there are minimal changes in EB and body composition. During the early pre-season, training volume is highest, through the use of various training modes, (Juhari et al., 2018) which may explain the greater net energy deficit in PS1 in the current study. As such, EB and body composition differ between different phases of the season, which may provide preliminary evidence of body composition periodization in team sport athletes.

Although it is thought that an energy surplus is needed to increase muscle mass, (Aragon et al., 2017) data indicates that with adequate protein intake muscle mass can be maintained and/or increased when in energy deficit (Carbone, McClung, & Pasiakos, 2019). In the current study, increases in FFSTM during OS and PS1 occurred in states of EB and energy deficit, respectively. Consistent with most high-performance programmes, athletes received individualized nutritional plans, tailored specifically to their training and body composition goals. Whilst it is difficult to determine specifically the reasons for the changes during OS and PS1 without knowing the specific macronutrient and energy intake for each phase, a possible explanation could be an increase in overall protein intake. Indeed, when increases in muscle mass are the goal of a training programme, athletes are typically advised to supplement with increased protein intake. This may explain why increases in FFSTM

occurred despite being in an energy deficit (Longland, Oikawa, Mitchell, Devries, & Phillips, 2016). Consistent also with a recent position stand, (Aragon et al., 2017) these data demonstrate that the greater the energy deficit, the greater the loss in FM (see Figure 1, Table I). Collectively, this suggests a close relationship exists between EB and changes in body composition, that may also be targeted at specific times across a season.

Despite the positive changes that can occur in FM, and at times FFSTM, when in an energy deficit, it is unclear how long athletes may remain in energy deficit, before it becomes harmful. Based on predicted liver glycogen, it is suggested that a threshold of  $\pm 400 \text{ kcal}\cdot\text{day}^{-1}$  represents a hypothetical limit for a desirable EB (Benardot, 2007; Benardot, 2013; Deutz, Benardot, Martin, & Cody, 2000). Further, sustained daily energy deficit is associated with suppression of resting metabolic rate, (Saltzman & Roberts, 1995) higher bodyfat, (Benardot, 1996) altered endocrine function, (Elliott-Sale, Tenforde, Parziale, Holtzman, & Ackerman, 2018) higher injury rates (Schlabach, 1994) and impaired physical performance (Murphy et al., 2018). During PS1, 39/45 (87%) of the athletes were in energy deficit (mean  $\pm$  SD;  $-229 \pm 222 \text{ kcal}\cdot\text{day}^{-1}$ ), which is within the proposed hypothetical limit of  $400 \text{ kcal}\cdot\text{day}^{-1}$ . During this time, FFSTM also increased ( $1.6 \pm 1.9 \text{ kg}$ ) and FM decreased ( $-1.4 \pm 1.3 \text{ kg}$ ), suggesting that at selected times of the season, body composition is optimized. In addition, emerging evidence demonstrates that relative energy deficiency in sport (RED-S) is prevalent in male athletes (Burke, Close, et al., 2018). In pre-season 1 (a period of  $67 \pm 12 \text{ days}$  [ $\sim 9 \text{ weeks}$ ]), 7 athletes presented with a daily energy deficit  $>400 \text{ kcal}\cdot\text{day}^{-1}$  (mean,  $647 \text{ kcal}\cdot\text{day}^{-1}$ ) with the greatest being  $-935 \text{ kcal}\cdot\text{day}^{-1}$ . This deficit is similar to unpublished data from a mixed martial arts athlete (Kasper et al., 2019) who had an energy deficit of  $-869 \text{ kcal}\cdot\text{day}^{-1}$  during an 8-week pre-competition camp, and almost as high as the reported  $5.0 \text{ MJ}\cdot\text{day}^{-1}$  ( $-1195 \text{ kcal}\cdot\text{day}^{-1}$ ) energy deficit observed in military soldiers during 8 weeks of combat leadership training (Friedl et al., 1994). Additionally, the mean of the 7 athletes whose energy deficit was  $>400 \text{ kcal}\cdot\text{day}^{-1}$  is comparable to a previous report (Fortes et al., 2011) where 8 weeks of military training led to decrements in physical performance and body composition. Whilst the clinical and performance outcomes of the current study cannot be demonstrated, anecdotally, there were no reports of any of athletes experiencing energy deficiency-induced health and/or performance consequences. Nevertheless, practitioners should consider athletes with particularly challenging body composition goals (especially for FM) and provide the necessary support (Mountjoy et al., 2015).

In addition to assessing the relationship between changes in FFSTM, FM and EB, the relationship between changes in BM and EB was investigated. Herein, these findings demonstrated that BM has the weakest relationship with EB when compared with FM and FFSTM. Whilst this might be an expected observation due to EB being quantified from changes in body energy stores, i.e. FM and FFSTM, it should be recognized that only 17% of the changes in FFSTM were explained by EB, and that FFSTM changes occurred in states of energy surplus, balance and deficit. Conversely, FM was decreased and increased in states of energy deficit and surplus, respectively. Moreover, these data are consistent with previous data in Australian rules football, where changes in body composition occur independent of that of BM (Bilsborough et al., 2016). This indicates that singularly obtaining measurements of BM alone, are poor determinants of body composition, and therefore, appropriate measures, including that of EB, should be obtained to understand training and nutrition practices of athletes and more comprehensive changes in body composition.

From a practical perspective, the true value of any intervention is determined by whether they may influence practice. Indeed, the current study suggests that longer term measurements of EB, obtained via DXA-derived changes in body energy stores, can be used as an educational tool to provide information about athletes training and nutrition practices/behaviours over an extended period of time. Furthermore, the tool of estimating EB from DXA changes can provide knowledge of the potentially extreme practices that athletes undertake to achieve challenging body composition goals (i.e. fat mass). Therefore, in the future, this will help practitioners in providing the appropriate support to athletes to ensure that performance and health is maintained.

Whilst this study presents novel information about determining EB from changes in FM and FFSTM in team sports, it is not without limitations. Indeed, there is no information about the athletes' energy intake and expenditure, which may have been useful alongside the EB data. However, assessing energy intake and expenditure of a team of 45 athletes for a given time period is logistically unfeasible in applied settings. In addition to the previously described issues in assessing energy intake and expenditure, (Burke, Lundy, et al., 2018) 3–7 day snapshots (the time-course often used) may not be representative of longer time frames, such as  $\geq 60$  days used in the current study. Routinely DXA scanning athletes may also be problematic for some athletes, sports and organizations due to the cost and logistical challenges of scanning multiple athletes several times across a season. Furthermore,

practitioners should be aware that each scan emits a dose (albeit a very small amount and no more than a long-haul flight) of ionizing radiation to the athlete. Nevertheless, future research should aim to identify desired levels of EB that lead to achieving body composition goals, but which does not lead to performance declines.

## Conclusion

This study demonstrates that gains in FFSTM can be achieved in states of energy deficit, balance and surplus. Further, regular DXA assessments of body composition can be used as an educational tool to infer longer term changes in EB, which practically can be used as a reasonable global assessment of training and nutrition practices/behaviours. This information will facilitate practitioners when altering athletes plans to achieve body compositional goals.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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