



Original Research

Changes in markers of body composition of professional male soccer players during pre-season

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ABSTRACT

To evaluate changes achieved in whole-body and regional (upper limbs, lower limbs, and trunk) estimates of body composition, twenty professional male soccer players (7 defenders, 7 midfielders, 6 forwards) underwent dual-energy x-ray absorptiometry (DXA) analysis at the beginning and end of pre-season. Measures included: mass, fat mass (FM), fat-free mass (FFM), and body fat per cent (BF%). Players' activity during on-field training sessions was monitored using Global Positioning System (GPS) units, with GPS data used to obtain estimations of energy expenditure (EE). Whole-body mass remained unchanged across the pre-season. Moderate significant increases and decreases were achieved in whole-body FFM (Pre: 59.58 ± 5.27 kg; Post: 60.61 ± 5.18 kg; $p = 0.001$; $d = 0.87$) and FM (Pre: 10.60 ± 1.88 kg; Post: 9.56 ± 1.81 kg; $p = 0.001$; $d = 0.85$), respectively. Moderate significant decreases were achieved in whole-body BF% (Pre: $14.4 \pm 2.3\%$; Post: $12.9 \pm 2.0\%$; $p < 0.001$; $d = 0.94$). No significant inter-positional differences were observed for the changes achieved in any global or regional estimate of body composition. Total EE was significantly correlated with Δ FM ($r = 0.65$, $p = 0.002$), Δ FFM ($r = 0.46$, $p = 0.03$), and Δ BF% ($r = 0.67$, $p = 0.002$). The total EE of pre-season training accounted for 42%, 21%, and 45% of the variance in Δ FM, Δ FFM, and Δ BF%, respectively. These findings suggest that the pre-season period is a suitable time for initiating favourable alterations in body composition following the off-season in elite soccer players.

Introduction

The maintenance of an appropriate body composition is an important requisite in the physical conditioning of elite soccer players.¹ Intuitively, excess body fat represents an inert load likely to impair physical performance and predispose players to a heightened risk of all-cause injury.² Conversely, the fat-free compartment of the body, constituting lean muscle and bone mineral mass, plays a key role in strength and power performance and forms an integral component of the physical make-up of the elite soccer player.³ The routine measurement of body composition is therefore a useful practice in professional soccer and is commonly undertaken to assess players' readiness for competition and monitor the effectiveness of dietary and training interventions.¹

As is commonplace within many team sports, soccer adopts a cyclical

pattern of competition, where the cessation of the competitive season is followed by a period of planned rest and recuperation. This period of inactivity and reduced training, the so-called off-season, typically lasts between 4 and 6 weeks, and may adversely affect measures of body composition.⁴ In a recent study of 19 elite male soccer players, significant increases in body fat per cent (BF%) were observed following a 6-week off-season period, with changes mediated through increases in whole-body fat mass (FM) and reductions in the fat-free mass (FFM) of the lower limbs.⁵ Given the deleterious effects that such outcomes may have on parameters of match-related fitness such as speed, power, and high-intensity running performance,⁶ reversing such trends prior to the return to competition is desirable.

To facilitate the return to competition and provide players with the opportunity to establish the physical base from which technical and

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tactical development can occur, an intensive pre-season training programme is commonly undertaken.⁷ In comparison to the in-season where professional players may complete an average of three training sessions per week,⁸ training loads (TL) are generally increased up to 2–4 times during the pre-season.⁹ Consequently, energy expenditure (EE) will be elevated during this phase of the season.¹⁰ Accordingly, energy intake (EI) should be modified in relation to the body composition goals of the player.¹¹ During the in-season, players typically match EI with their daily energy requirements to avoid hindering performance.¹² However, when alterations in FM and body composition are sought, energy deficits may be necessary.¹³ Pre-season therefore represents a unique opportunity to reverse the negative changes observed in markers of body composition following the off-season through the systematic increase of TL and the provision of individualised dietary regimes.

In contrast to the volume of research concerning the impact of pre-season training on parameters of physical fitness,^{14,15} a dearth of information appears available on its impact on markers of body composition. Literature examining seasonal changes in the body composition of professional soccer players have typically observed decreases in FM and increases in FFM from the beginning of pre-season to mid-season.¹⁶ However, without a post pre-season assessment of body composition, the role of the pre-season in these changes is unclear. Additionally, studies utilising two-compartment techniques such as skinfolds and bioelectrical impedance analysis (BIA) have returned conflicting results.^{7,17,18} Although such techniques represent practical methods within the field, the accuracy in which BF% may be estimated from skinfold thicknesses can vary greatly depending upon the anthropometric equation utilised.^{19,20} Dual-energy x-ray absorptiometry (DXA), however, is widely regarded as the criterion reference standard for assessing body composition within team sport athletes given its potential to provide a three-compartmental overview of body composition.¹⁹ Nevertheless, the use of DXA within most sports settings is often limited due to its associated logistical and financial costs.²⁰

To our knowledge, two studies have previously utilised DXA to document body composition changes during the pre-season within elite soccer players.^{21,22} In a cohort of 18 A-League soccer players, improvements in body composition were achieved following a ~3-month pre-season.²² Similarly, favourable alterations (decreases/increases in FM/FFM, respectively) were observed within English Premier League players following 6 weeks of pre-season training.²¹ However, given the potential impact that differences in culture, competition demands and playing position have upon playing style and training practices,²³ additional research is required to document the changes incurred in body composition during the pre-season amongst elite cohorts from varying competitions. Furthermore, the extent to which changes in body composition may be attributed to the TL and EE induced during pre-season remains unclear. Understanding such relationships may be of benefit to support staff working with elite soccer players during the pre-season, and provide valuable information from which to base the prescription of TL and nutritional guidelines. This investigation therefore aimed to expand upon the available literature and document body composition changes induced during the pre-season within players belonging to one of Europe's leading soccer clubs (FC Barcelona). Accordingly, we sought to: 1) evaluate changes in global and regional markers of body composition over the pre-season period; 2) examine the impact of playing position upon these changes; and 3) explore what proportion of the variability in changes in body composition may be explained by the total EE associated with pre-season training.

Methods

Participants

Twenty male soccer players (age: 25.1 ± 4.1 y; stature: 177.0 ± 6.9 cm; body mass: 73.8 ± 6.0 kg) belonging to the first team of FC Barcelona provided informed consent to participate in this study.

Players were separated into their outfield playing positions for analyses (defenders: $n = 7$; midfielders: $n = 7$; forwards: $n = 6$). Over the course of the two competitive seasons evaluated (2014–2015 and 2015–2016), the club achieved considerable success, winning two La Liga titles, two Copa del Rey titles, and one UEFA Champions League title. Whilst assessments of body composition were completed as part of the routine medical screening of players, data procurement and handling conformed to the recommendations outlined within the Declaration of Helsinki and the study received approval from the Ethics Committee for Clinical Research of the Catalan Sports Council.

Design

Measures of whole-body and regional (upper limb, lower limb, trunk) mass, FM, FFM, and BF% were assessed by DXA (GE Healthcare Lunar, Madison, WI). Assessments were undertaken 38 ± 10 days apart at the start and end of the pre-season during either the 2014–2015 ($n = 16$) or 2015–2016 ($n = 4$) competitive seasons. These timeframes were dictated by the club and reflect previous literature.^{18,21} In accordance with standardised protocols that are recognised as best practice, scans were performed and analysed by the same trained operator and were undertaken in a rested and hydrated state.²⁴ Specifically, players presented to the lab having not undertaken any exercise on the morning of the scans and had refrained from the consumption of food in the 3–4 h previous.²⁴ The players had also been instructed to consume fluids ad-libitum prior to scans. The test-retest reliability of the DXA scanner for measurement of whole-body and regional body composition in non-obese adults, with repositioning between scans, has been previously documented.²⁵ Briefly, the coefficient of variation (CV) for whole-body FM and FFM were 1.0% and 0.5%, respectively. Regional reliability estimates for FM were as follows: upper limbs, 2.8%; lower limbs, 1.6%; and trunk, 2.0%. Regional reliability estimates for FFM were: upper limbs, 1.6%; lower limbs, 1.3%; and trunk, 1.0%.

Pre-season training and nutritional practices

Pre-season training, as programmed and directed by the coaching staff, was comparable prior to the start of both the 2014–2015 (36 sessions, 5 matches) and 2015–2016 (33 sessions, 8 matches) competitive seasons. The mean number of on-field training sessions performed was 21 ± 10 sessions, with variation attributable to each player's unique circumstances (date of return to pre-season following international competition, injury, fatigue management etc.). In line with the unique playing and training philosophy embedded at FC Barcelona, training sessions incorporated integrated content whereby tactical, technical, and physical factors were amalgamated.²³ Players' locomotive activities were recorded during each training session using portable 10-Hz Global Positioning System (GPS) units (Viper Pod, Statsports, Northern Ireland). To avoid inter-unit error, each player wore the same device during the entirety of the study period.²⁶ Following each training session, GPS data were extracted and analysed using propriety software (Viper, Statsports) to derive: total distance (TD); high-speed running distance (HSR; 19.8–25.09 km·h⁻¹); sprinting distance (SPR; ≥25.1 km·h⁻¹); and number of accelerations (ACC; >3 m·s⁻²) and decelerations (DEC; >3 m·s⁻²). Intensity thresholds were established based upon previous literature and are consistent with those commonly used by professional soccer clubs.^{27,28} GPS data were also used to estimate the average metabolic power (AMP; W·kg⁻¹), total energy cost (EC; kJ·kg⁻¹), and EE (kcal) associated with on-field training sessions according to the approach of di Prampero and Osngach.²⁹ In particular, this approach relies on the theoretical construct that metabolic demands can be estimated from the instantaneous speed and acceleration, and the known EC of accelerated/decelerated locomotion which characterise soccer-related activities.³⁰ Acceptable accuracy and validity have been advocated in support of these metabolic estimates as practical tools in team-sport demands analysis, especially following a recent update of the original model,³¹

which now differentiates between the EC of running and walking, and also considers the cost of air resistance. The full GPS data set included 18 players with weekly analyses inclusive only of those who completed $\geq 75\%$ of on-field sessions for that week.

Nutritional practices were informed by the club's nutritional adviser and remained consistent across each pre-season. The general objective of the nutritional advice provided to the players was to support an optimal adaptation to the enhanced TL induced during pre-season as well as promote decreases/increases in FM/FFM, respectively. Additionally, players were provided with individualised nutritional goals based upon the result of their baseline DXA measurement. Subject to the specific nutritional goals of the player, recommended macronutrient intakes were as follows: carbohydrate (4.0–6.0 g/kg/day); protein (1.8–2.0 g/kg/day); and fat (1.0 g/kg/day). Based upon these guidelines, the recommended daily EI was ~ 2795 kcal (range: 2648–3080 kcal). During pre-season, all meals and snacks were provided by the club and players were encouraged to work closely with the club's nutritional advisor to translate their recommended nutrient guidelines into food equivalents.

Statistical analysis

Prior to the use of parametric statistical test procedures, normality of distribution and homogeneity of variance were verified using Shapiro-Wilk's and Levene's tests, respectively. Changes in estimates of body composition were assessed using one-way analysis of variance (ANOVA) with two-way ANOVAs (factor: time; playing position) used to examine whether the changes achieved in estimates of body composition were related to playing position. Mean standardised differences are reported as Cohen's d with the following criteria used to interpret the practical significance of findings: trivial, < 0.2 ; small, 0.21 – 0.6 ; moderate, 0.61 – 1.2 ; large, 1.21 – 1.99 ; and very large, ≥ 2.0 .³² In addition, the smallest worthwhile change (SWC) was calculated for each variable as the between-player standard deviation multiplied by 0.2 .³³ To assess the relationship between independent (total EE of pre-season training) and dependent (Δ FM, Δ FFM, Δ BF%) variables, multiple linear regressions were performed. Prior to regression analyses, Pearson's correlation

coefficients (r) were used to indicate whether the magnitude of the relationship between variables was small (0.10 – 0.29), moderate (0.30 – 0.49), large (0.50 – 0.69), very large (0.70 – 0.89), and nearly perfect (≥ 0.90).³² Data are presented as means and standard deviations (mean \pm SD). Weekly TL and EE data are presented for descriptive purposes only. Statistical procedures were completed using Statistical Package for Social Sciences (SPSS 22.0, IBM, USA) and statistical significance was set at $p < 0.05$.

Results

Changes in global and regional markers of body composition

Table 1 reports the changes in markers of body composition between the beginning and end of pre-season.

Whole-body total mass remained unchanged following pre-season ($d = 0.00$; 95% CI: -0.66 to 0.66 kg; $p = 0.99$). When analysed regionally, no differences were observed in total mass of the upper limbs ($d = 0.37$; 95% CI: -0.15 to 0.02 kg; $p = 0.11$), lower limbs ($d = 0.19$; 95% CI: -0.36 to 0.15 kg; $p = 0.41$), or trunk ($d = 0.34$; 95% CI: -0.12 to 0.76 kg; $p = 0.14$).

Moderate significant reductions in whole-body FM ($d = 0.85$; 95% CI: -0.47 to -0.28 kg; $p = 0.001$) were observed following pre-season with reductions occurring in the upper limbs ($d = 0.69$; 95% CI: -0.18 to -0.04 kg; $p = 0.006$), lower limbs ($d = 0.97$; 95% CI: -0.53 to -0.19 kg; $p < 0.001$) and trunk ($d = 0.70$; 95% CI: -0.91 to -0.18 kg; $p = 0.006$).

Moderate significant increases in whole-body FFM ($d = 0.87$; 95% CI: 0.48 – 1.59 kg; $p = 0.001$) were mediated through increases in FFM of the lower limbs ($d = 0.51$; 95% CI: 0.02 – 0.48 kg; $p = 0.03$) and trunk ($d = 1.17$; 95% CI: 0.52 – 1.21 kg; $p < 0.001$). The FFM of the upper limbs remained unchanged ($d = 0.22$; 95% CI: -0.05 to 0.13 kg; $p = 0.34$) following pre-season.

Moderate significant decreases occurred in whole-body BF% following pre-season ($d = 0.94$; 95% CI: -2.2 to -0.7% ; $p < 0.001$) with reductions occurring in the upper limbs ($d = 0.68$; 95% CI: -2.1 to -0.4% ; $p = 0.006$), lower limbs ($d = 1.03$; 95% CI: -1.89 to -0.70% ;

Table 1

Changes in global (whole-body) and regional (upper limbs, lower limbs, trunk) markers of body composition between start and end of pre-season within outfield players ($n = 20$).

	Defenders ($n = 7$)		Midfielders ($n = 7$)		Forwards ($n = 6$)		All players ($n = 20$)		SWC
	Start	End	Start	End	Start	End	Start	End	
Global									
<i>Whole-body</i>									
Total mass (kg)	75.37 \pm 5.64	74.79 \pm 5.85	72.34 \pm 4.35	73.76 \pm 4.64	73.51 \pm 8.15	75.25 \pm 9.14	73.75 \pm 5.93	73.75 \pm 6.35	1.19
FM (kg)	9.84 \pm 1.89	8.62 \pm 1.77	11.55 \pm 2.07	10.43 \pm 1.65	10.40 \pm 1.36	10.04 \pm 1.75	10.60 \pm 1.88	9.56 \pm 1.81 [‡]	0.38
FFM (kg)	61.83 \pm 4.58	62.49 \pm 4.47	57.36 \pm 2.72	59.81 \pm 3.10	59.54 \pm 7.58	61.55 \pm 7.99	59.58 \pm 5.27	60.61 \pm 5.18 [‡]	1.05
BF% (%)	13.0 \pm 1.9	11.5 \pm 1.7	16.0 \pm 1.8	14.1 \pm 1.5	14.0 \pm 2.3	13.4 \pm 2.0	14.4 \pm 2.3	12.9 \pm 2.0 [#]	0.5
Regional									
<i>Upper limbs</i>									
Total mass (kg)	8.54 \pm 0.56	8.41 \pm 0.54	8.01 \pm 0.59	8.18 \pm 0.63	8.20 \pm 0.98	8.31 \pm 1.06	8.25 \pm 0.72	8.19 \pm 0.73	0.14
FM (kg)	0.98 \pm 0.12	0.86 \pm 0.11	1.13 \pm 0.16	1.00 \pm 0.19	0.94 \pm 0.11	0.89 \pm 0.15	1.02 \pm 0.15	0.91 \pm 0.14 [‡]	0.03
FFM (kg)	7.10 \pm 0.54	7.09 \pm 0.47	6.47 \pm 0.47	6.75 \pm 0.46	6.83 \pm 0.98	6.97 \pm 1.04	6.80 \pm 0.70	6.84 \pm 0.66	0.14
BF% (%)	11.6 \pm 1.6	10.2 \pm 1.2	14.0 \pm 1.5	12.1 \pm 1.7	11.6 \pm 2.4	10.9 \pm 2.3	12.4 \pm 2.1	11.1 \pm 1.9 [‡]	0.4
<i>Lower limbs</i>									
Total mass (kg)	27.81 \pm 2.33	27.46 \pm 2.14	26.72 \pm 1.95	27.21 \pm 2.30	27.23 \pm 2.52	27.92 \pm 3.25	27.25 \pm 2.19	27.15 \pm 2.35	0.44
FM (kg)	3.36 \pm 0.69	2.99 \pm 0.55	4.05 \pm 0.64	3.71 \pm 0.69	3.51 \pm 0.52	3.37 \pm 0.42	3.65 \pm 0.67	3.29 \pm 0.58 [#]	0.13
FFM (kg)	22.91 \pm 2.20	22.93 \pm 1.92	21.25 \pm 1.43	22.04 \pm 1.63	22.24 \pm 2.46	23.02 \pm 3.03	22.13 \pm 2.07	22.38 \pm 2.08 [*]	0.41
BF% (%)	12.1 \pm 2.6	10.9 \pm 1.9	15.1 \pm 1.8	13.6 \pm 1.6	13.0 \pm 2.5	12.2 \pm 2.0	13.4 \pm 2.5	12.1 \pm 2.0 [#]	0.5
<i>Trunk</i>									
Total mass (kg)	33.41 \pm 3.21	33.45 \pm 3.41	31.81 \pm 2.16	32.70 \pm 2.01	32.48 \pm 4.43	33.52 \pm 4.56	32.57 \pm 3.22	32.89 \pm 3.36	0.64
FM (kg)	4.50 \pm 1.12	3.81 \pm 1.18	5.32 \pm 1.43	4.71 \pm 0.90	4.95 \pm 1.12	4.79 \pm 1.30	4.92 \pm 1.23	4.38 \pm 1.21 [‡]	0.25
FFM (kg)	27.82 \pm 2.29	28.56 \pm 2.31	25.46 \pm 1.37	26.93 \pm 1.35	26.45 \pm 3.90	27.62 \pm 3.69	26.58 \pm 2.70	27.44 \pm 2.55 [#]	0.54
BF% (%)	13.4 \pm 2.3	11.2 \pm 2.3	16.6 \pm 3.4	14.3 \pm 2.0	15.3 \pm 3.3	14.3 \pm 2.8	15.1 \pm 3.2	13.2 \pm 2.7 [‡]	0.6

Data presented as mean \pm SD.

FM, fat mass; FFM, fat-free mass; BF%, body fat per cent; SWC, smallest worthwhile change.

* significantly different from start of pre-season ($p < 0.05$).

[‡] significantly different from start of pre-season ($p < 0.01$).

[#] significantly different from start of pre-season ($p < 0.001$).

$p < 0.001$), and trunk ($d = 0.87$; 95% CI: -2.91 to -0.87% ; $p = 0.001$).

No significant inter-positional differences were observed for any global ($p \geq 0.10$; $d \leq 0.50$) or regional ($p \geq 0.08$; $d \leq 0.59$) estimate of body composition across the pre-season period.

Weekly training load (TL) and energy cost (EC) of on-field training sessions

An overview of the TL accumulated across weeks 1–6 of the pre-season is presented in Table 2 whilst the mean EC of on-field training sessions during each of these weeks is presented within Table 3. The data presented pertains to on-field training sessions only and does not include data from pre-season match play.

Relationship between changes in body composition and the total energy expenditure (EE) associated with pre-season training.

The total EE of pre-season training was 9369 ± 5424 kcal. Total EE was significantly correlated with ΔFM ($r = 0.65$, $p = 0.002$), ΔFFM ($r = 0.46$, $p = 0.032$), and $\Delta BF\%$ ($r = 0.67$, $p = 0.002$). The total EE of pre-season training accounted for 42%, 21%, and 45% of the variance in ΔFM , ΔFFM , and $\Delta BF\%$, respectively.

Discussion

We sought to investigate the changes incurred in global and regional markers of body composition during the pre-season within a cohort of elite male soccer players. At the global level, reductions in BF% were mediated through reductions in FM and increases in FFM. Regionally, reductions in the FM of the upper limbs, lower limbs and trunk were accompanied by concomitant increases in the FFM of the lower limbs and trunk. Moreover, the changes observed in all global and regional estimates of body composition were similar between playing positions. An additional aim was to identify what proportion of the variability in changes in body composition could be explained by the total EE associated with pre-season training. The total EE of pre-season training

Table 2

Accumulated training loads (TL) reported across each 1-week microcycle of the pre-season.

	Duration (min)	TD (m)	HSR (m)	SPR (m)	ACC (n)	DEC (n)
Week 1						
DEF (n = 1)	565 ± 0	32,752 ± 0	942 ± 0	61 ± 0	938 ± 0	860 ± 0
MID (n = 3)	535 ± 45	30,219 ± 3568	1467 ± 1307	112 ± 157	896 ± 77	842 ± 81
ATT (n = 2)	655 ± 346	27,740 ± 2161	830 ± 337	85 ± 74	250 ± 45	273 ± 18
ALL (n = 6)	580 ± 168	29,815 ± 3094	1167 ± 903	95 ± 107	688 ± 344	655 ± 301
Week 2						
DEF (n = 2)	529 ± 250	31,354 ± 14,137	907 ± 341	130 ± 93	1035 ± 540	953 ± 538
MID (n = 7)	544 ± 176	31,013 ± 10,533	1736 ± 1439	76 ± 79	962 ± 388	870 ± 431
ATT (n = 3)	262 ± 114	14,507 ± 5617	523 ± 342	65 ± 58	262 ± 311	281 ± 270
ALL (n = 12)	471 ± 202	26,943 ± 11,861	1294 ± 1215	82 ± 73	799 ± 482	737 ± 466
Week 3						
DEF (n = 2)	645 ± 175	36,580 ± 6205	1061 ± 1	231 ± 123	1049 ± 268	961 ± 212
MID (n = 7)	739 ± 39	39,933 ± 3531	2144 ± 1502	32 ± 27	1114 ± 158	1079 ± 109
ATT (n = 4)	363 ± 301	21,370 ± 15,834	832 ± 580	144 ± 174	467 ± 529	394 ± 534
ALL (n = 13)	609 ± 237	33,705 ± 12,118	1574 ± 1277	97 ± 124	905 ± 426	850 ± 428
Week 4						
DEF (n = 5)	215 ± 108	12,437 ± 6327	454 ± 229	84 ± 161	351 ± 164	323 ± 158
MID (n = 7)	332 ± 105	17,644 ± 6358	976 ± 658	71 ± 75	483 ± 195	446 ± 204
ATT (n = 4)	258 ± 102	16,104 ± 5225	653 ± 295	153 ± 134	318 ± 248	304 ± 225
ALL (n = 16)	277 ± 111	15,632 ± 6137	732 ± 510	96 ± 118	400 ± 201	372 ± 195
Week 5						
DEF (n = 5)	242 ± 51	14,835 ± 2722	424 ± 124	88 ± 92	410 ± 79	377 ± 67
MID (n = 7)	248 ± 97	14,762 ± 5684	795 ± 641	16 ± 14	383 ± 146	383 ± 144
ATT (n = 4)	204 ± 109	12,231 ± 6799	520 ± 146	83 ± 105	274 ± 218	277 ± 203
ALL (n = 16)	235 ± 85	14,152 ± 5046	611 ± 450	55 ± 76	364 ± 151	355 ± 141
Week 6						
DEF (n = 5)	386 ± 44	22,468 ± 2292	895 ± 169	228 ± 87	572 ± 43	535 ± 59
MID (n = 7)	379 ± 84	20,365 ± 5572	956 ± 502	61 ± 66	494 ± 186	474 ± 184
ATT (n = 4)	256 ± 175	13,323 ± 8547	854 ± 1146	121 ± 65	301 ± 284	279 ± 266
ALL (n = 16)	345 ± 119	18,912 ± 6772	908 ± 657	128 ± 98	460 ± 214	435 ± 206

Data presented as mean ± SD and are stratified by playing position (DEF, defender; MID, midfielder; ATT, attacker; ALL, all positions).

TD, total distance; HSR, high-speed running distance ($m > 19.8 \text{ km}\cdot\text{h}^{-1}$); SPR, sprinting distance ($m > 25.2 \text{ km}\cdot\text{h}^{-1}$); ACC, number of accelerations ($>3 \text{ m}\cdot\text{s}^{-2}$); DEC, number of decelerations ($<-3 \text{ m}\cdot\text{s}^{-2}$).

Table 3

Mean estimated energy cost of on-field training sessions during each 1-week microcycle of the pre-season.

	AMP ($\text{W}\cdot\text{kg}^{-1}$)	EC ($\text{kJ}\cdot\text{kg}^{-1}$)	EE (kcal)
Week 1			
DEF (n = 1)	5.5 ± 0.5	46.1 ± 12.4	824 ± 222
MID (n = 3)	5.5 ± 0.2	42.8 ± 12.3	727 ± 223
ATT (n = 2)	6.8 ± 0.7	31.9 ± 11.1	581 ± 201
ALL (n = 6)	5.9 ± 0.2	36.6 ± 10.8	641 ± 179
Week 2			
DEF (n = 2)	5.6 ± 0.5	40.0 ± 14.4	715 ± 258
MID (n = 7)	5.5 ± 0.4	36.8 ± 9.2	636 ± 162
ATT (n = 3)	5.6 ± 1.2	26.7 ± 11.6	435 ± 189
ALL (n = 12)	5.5 ± 0.5	35.4 ± 8.4	611 ± 148
Week 3			
DEF (n = 2)	5.0 ± 1.0	46.7 ± 22.9	836 ± 409
MID (n = 7)	5.0 ± 0.8	46.1 ± 21.1	796 ± 363
ATT (n = 4)	5.6 ± 0.8	40.7 ± 27.9	644 ± 400
ALL (n = 13)	5.2 ± 0.8	37.5 ± 24.0	650 ± 399
Week 4			
DEF (n = 5)	5.0 ± 0.4	23.4 ± 9.8	421 ± 171
MID (n = 7)	4.9 ± 0.5	27.4 ± 13.7	477 ± 239
ATT (n = 4)	6.4 ± 1.8	22.7 ± 8.7	368 ± 134
ALL (n = 16)	6.1 ± 1.7	24.6 ± 10.2	418 ± 172
Week 5			
DEF (n = 5)	5.6 ± 0.1	38.6 ± 16.3	708 ± 310
MID (n = 7)	5.4 ± 0.5	43.1 ± 17.2	780 ± 258
ATT (n = 4)	6.0 ± 1.3	25.7 ± 19.7	422 ± 314
ALL (n = 16)	6.0 ± 1.3	24.2 ± 16.9	418 ± 302
Week 6			
DEF (n = 5)	5.3 ± 1.2	26.8 ± 7.1	490 ± 134
MID (n = 7)	5.1 ± 1.2	25.1 ± 7.8	433 ± 135
ATT (n = 4)	5.1 ± 0.9	23.3 ± 5.8	424 ± 114
ALL (n = 16)	5.2 ± 1.2	25.2 ± 7.0	447 ± 129

Data presented as mean ± SD and are stratified by playing position (DEF, defender; MID, midfielder; ATT, attacker; ALL, all positions).

AMP, average metabolic power; EC, energy cost; EE, energy expenditure.

accounted for 42%, 21%, and 45% of the variance in Δ FM, Δ FFM, and Δ BF%, respectively.

As evidenced, pre-season presents a suitable time by which favourable alterations in body composition may be achieved within elite soccer players. Our findings support those observed within English Premier League players whereby reductions (\sim 2%) in BF% were achieved following a 6-week pre-season.²¹ Conversely, the FFM and BF% of French League 1 players remained unchanged following pre-season.¹⁷ Although we are unable to discount whether such discrepancies are simply an artefact of the different assessment methods, one explanation may reside in potential disparities in the pre-season duration. In the present study, measurements were obtained \sim 6 weeks apart; however, the duration of the pre-season employed by Carling and Orhant was not noted.¹⁷ The duration of pre-season employed within the aforementioned study may therefore have been insufficient to promote such changes; however, without such information, this remains speculative. Another explanation likely relates to the type and intensity of the pre-season training stimulus. As shown, differences in the total EE associated with pre-season training accounted for 42% of the variance in Δ FM. The increased energy cost of training reflects the up-regulation of oxidative metabolism, with exercise intensity representing the greatest moderator of substrate utilization.³⁴ Additionally, the intermittent nature of soccer-specific exercise has been found to promote a high rate of lipolysis and the release of free fatty acids into the blood.³⁵ In the context of the studied club, a unique training philosophy is embedded whereby there is a marked disposition for on-field game-related training, through which tactical, technical and physical factors are amalgamated.²³ Conversely, only 21% of the variance in Δ FFM was attributable to the total EE associated with pre-season training. This is perhaps unsurprising given that training-induced increases in muscle hypertrophy are not driven by EE per se.³⁶

As discussed, favourable alterations in DXA-derived estimates of body composition have previously been reported within elite English Premier League players following \sim 6-weeks of pre-season training.²¹ Nevertheless, as differences in culture and competition demands may result in distinct training practices, data derived from additional competitions is warranted.²³ Additionally, the present investigation is the first to report body composition changes induced during pre-season within elite soccer players, in relation to metrics of TL. This represents an important contribution to the literature as indications of TL and the associated EE are necessary when interpreting alterations in body composition.¹¹ When considering the TL accumulated across each week of pre-season, the mean weekly TD and HSR distance observed in the present study was 23193 m and 1048 m, respectively. Such values exceed those reported for elite players during the in-season,¹² thus supporting observations of enhanced TL during the pre-season in comparison to the in-season.⁹ Interestingly, the mean weekly TD observed within the present study is substantially lower than that reported for elite English Premier League players during pre-season.⁹ As FC Barcelona adopt a unique playing style, such discrepancies in loading patterns likely relate to differences in training practices.²³

Based upon measures of metabolic power, the mean EC of on-field training during weeks 1–3 was \sim 36 kJ \cdot kg⁻¹.²⁹ Whilst such figures remain below those associated with match play,²⁷ they exceed the \sim 25 kJ \cdot kg⁻¹ reported for elite players during the in-season.³⁷ Conversely, the reduced training volume observed during weeks 4–6 resulted in a mean EC of training more closely aligned with that of the in-season. A likely explanation for this pertains to the more frequent scheduling of matches during the latter stages of pre-season. Whilst we report TL and EE data to aid the interpretation of our findings, this data relates to on-field sessions only, and is not reflective of gym-based training sessions or the load associated with match play. Consequently, a conservative account of the demands imposed during pre-season is presented. Nevertheless, given that the estimated EE of match play ranges from 1200 to 1500 kcal,²⁷ the greater match participation exhibited during weeks 4–6 is likely to have compensated for the reduced training volume. This represents an important consideration for applied

practitioners preparing athletes during the pre-season, as the scheduling of matches will impact upon the programming of training, and will ultimately contribute towards their physical conditioning.

Several limitations warrant consideration when interpreting these results. Whilst we provide surrogate markers of EE to contextualise our findings, the limitations of the adopted approach should be acknowledged in comparison to the doubly labelled water method. Additionally, although we provide details concerning the nutritional guidelines provided to the players, we are unable to confirm their actual EI. Future research incorporating direct measurements of EE and EI is therefore necessary in order to fully examine the interaction of energy balance and body composition changes within elite soccer players during the pre-season. Another limitation relates to our relatively small sample size, a challenge commonly encountered when conducting applied research with elite cohorts. In the context of the present investigation, the two studied pre-seasons coincided with international competitions (FIFA World Cup 2014 and CONMEBOL Copa América 2015). Consequently, although we report the impact of \sim 6 weeks of pre-season (38 ± 10 days) on markers of body composition, the return of players to the club for pre-season training was dictated by the player's individual commitments to their national teams. This represents an important consideration in the applied setting as the timing of a player's return will influence the programming of pre-season training. Future research may wish to examine the impact that such logistical challenges have upon the loading patterns programmed during the pre-season and their subsequent impact upon markers of physical performance and body composition.

The present findings provide additional evidence supporting the pre-season to be a suitable period for elite soccer players to achieve concomitant reductions/increases in FM/FFM, respectively. These findings have practical implications for support staff working to prepare elite soccer players for the upcoming competitive season and further demonstrate the potential for favourable alterations in body composition to be achieved during a \sim 6-week pre-season period.

Submission statement

The data reported in this manuscript have not been published elsewhere and the manuscript is not under consideration for publication in another journal.

Authors' contributions

All authors have participated in the research and/or article preparation. All authors have approved the final submitted article. Study concept and design: GPM, FD, VU; Data collection: FD, AL, AGD, EP; Data analysis: GPM, ADI, VU; Manuscript development: GPM, VU; Contribution to manuscript: FD, AL, AGD, EP, ADI.

Ethics statement

The study received approval from the Ethics Committee for Clinical Research of the Catalan Sports Council and all players provided informed written consent to participate in the study.

Conflict of interest

The authors report no conflicts of interest.

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