Heliyon 10 (2024) e24955

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Effects of 8 weeks pre-season training on physical fitness, heart rate variability and cognition in women soccer players

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ARTICLE INFO

Keywords:
Women soccer player
Physical fitness
Cognition
Sports activity

ABSTRACT

The aim of this study was to explore the variations (pre-post) of (i) Anthropometric measures: weight, body mass index, lean and muscle mass, (ii) Physical fitness: countermovement jump (CMJ) and $VO2_{max}$, (iii) heart rate variability (HRV) (recumbent and sitting): mean RR, RMSSD, NN50 and NN50 %, (iv) Psychomotor Vigilance Task, and v) SART: ACC Go, ACC NoGo and reaction times in semi-professional women soccer players from the second division of the Spanish League. The analysis indicated that lean mass improved after the observation period ($p = .05$, $d = -0.38$), while no other significant changes in anthropometric measures were observed. Additionally, CMJ and aerobic power were also improved ($p<.01$, $d>0.50$). The RMSSD [recumbent ($d = -0.73$) and sitting ($d = -0.52$)] and NN50 [recumbent ($d = -0.69$) and sitting ($d = -0.70$)] increased after the period of observation ($p < .05$). Reaction time also significantly improved after the period of observation [PVT ($d = 0.42$) and SART ($d = -0.89$)]. Correlations performed between measures revealed that smaller body mass and body mass index were largely associated with greater NN50 ($r < 0.83$, $p = .001$). Additionally, greater CMJ and aerobic fitness were associated with greater HRV [recumbent ($r = -51$, $p = .001$) and sitting ($r = -0.60$, $p = .01$). The main findings of this study were that there was no relationship between cognitive performance and physical fitness, but HRV was related to body composition and physical fitness during the pre-season in women soccer players.

1. Introduction

Women's soccer has seen an increase in participants since 2005 when there were 99 teams in the world cup to 181 teams in 2022 [1]. This increase has also occurred in the number of federative licences worldwide. In Spain, in 2005 there were 13,582 licences for women players, and in 2021, 47,013 licences [2]. Therefore, the number of studies in this field is also increasing, mainly due to the fact that this sport is high intensity and intermittent with incomplete recoveries [3], which entails a great deal of scientific and professional

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https://doi.org/10.1016/j.heliyon.2024.e24955
Received 8 June 2023; Received in revised form 17 January 2024; Accepted 17 January 2024
Available online 18 January 2024

interest in improving the physical fitness of the players.

The search for maximum performance could cause a high number of injuries [4] which are mostly concentrated in the women soccer players' lower bodies [5]. For this reason, the pre-season is used as a brief training period in which many high-intensity activities are concentrated, both on and off the field [6], in order to recover physical fitness after the off-season [7]. These actions cause physical, physiological, technical-tactical and, in addition, anthropometric changes [8]. For these reasons, taking into account that muscle fatigue increases during the pre-season period, the initial hypothesis of this study is that women soccer players increase their physical fitness and physiological and technical-tactical metrics and decrease their cognitive function, although the level of this decrease is currently unknown. It is necessary to control these physical actions to quantify the training load through the GPS technology that is currently widely used in women's soccer [9,10], and to manage the recovery states to optimally control muscle fatigue during training [11,12]. In addition, the positive and negative effects of the physiological measures, such as heart rate variability (HRV), maximum oxygen consumption ($VO2_{max}$) and other related metabolic variables, could be studied to design and adjust training programmes accordingly [13,14]. Women soccer players cover between 9 and 11 km per competitive match as a total distance [15–17]. This variable has been studied as an indicator of global performance [18], although it is suggested that these values could be influenced by the level of competition [19]. However, the capacity for maximum performance in sprints and maximum intensity actions are the key variables for individual and collective success in women's soccer [20,21].

Regarding HRV, it necessary to mention the sensitivity that HRV shows with cognitive processing [22]. In fact, the role of the cardiovascular fitness level is very important. In addition, it is well known that aerobic exercise and cardiovascular fitness benefit the autonomic regulation mechanism [23] and promote adaptation in brain structures that consequently affect cognitive performance [24–27]. So far, the studies that investigate the relationship among cardiovascular fitness, HRV and cognition, show an important relationship between baseline autonomic regulating values and the cognitive performance index. However, to the best of our knowledge, there are no previous studies investigating the pre-season in women soccer players; in fact, nor are there studies covering changes in cognitive function in women soccer players during the pre-season. During our daily lives and during the practice of physical activity, actions related to maintaining attention on certain objectives are carried out, which is the cognitive function of vigilance [28]. Vigilance allows us to respond quickly and effectively to the stimuli that arise [29]. In Science, this cognitive function can be assessed through psychomotor vigilance (PVY) tasks [30], which recent studies demonstrate fluctuations of this cognitive function during the performance of a task [31,32], which generally increases temporarily. The objective of the present study was to analyse the effect of the pre-season on body composition, and physical and cognitive conditions of semi-professional women soccer players.

2. Methods

2.1. Study design and experimental approach

This study is observational, cohort design and inferential. Fitness assessments were performed twice during the cohort. There were 8 weeks between the first and second assessments [July (2 weeks), August (four weeks) and September (two weeks)]. The aim was to explore the variations (pre-post) of (i) Anthropometric measures: Weight, Body Mass Index, Lean mass and Muscle, (ii) Physical fitness: CMJ height and $V02_{max}$, (iii) Heart Rate Variability (Recumbent and Sitting): Mean RR, RMSSD, NN50 and NN50 %, (iv) Psychomotor Vigilance Task, and v) SART: ACC Go, AC NoGo and Reaction Times. See Table 1.

2.2. Participants

Sixteen Spanish female soccer players from category 2 of the Spanish league agreed to participate in the study (Table 1). The following inclusion criteria were applied for sample selection: a) systematic soccer training and competitive experience of more than 5 years; b) not having suffered any injury during the 3 months prior to the evaluation; c) no medication intake; d) Have an attendance rate greater than 85 % of all sessions. Generally, training sessions included a warm-up, a main part, and a cool-down.

The objectives, evaluations, and procedure were explained, and it was made clear that voluntary participation was made and that they could decide to withdraw from participating at any time. Furthermore, the anonymous nature of the study was explained. The players signed the informed consent. The study was carried out in accordance with the ethical principles of the Declaration of Helsinki for Research on Humans and was approved by the Ethics Committee of the Pontifical University of Mallorca (code: 2021/65).

2.3. Apparatus and materials

Participants were fitted with a Polar RS800 CX monitor (Polar Electro, Finland) to record their HRV during both assessments.

Height was measured using a stadiometer (SECA 213, Birmingham, UK) to the nearest 0.1 cm, and Body Mass Index, Lean Mass and

Table 1
Timeline of this study.

	2022										
Months		July		August				September			
Week		1	2	3	4	5	6		7	8	
	Pre	Pre-Season									Post

Muscle was measured without shoes with a bioelectrical impedance analysis (BIA) device (Tanita BC-730) to the nearest 0.1 kg.

An iPhone 5s (iOS version 12.4.5) was used to present the stimuli of the PVT and SART. These devices were previously blocked for any other type of notification. The centre of the screen was situated about 50–90 cm from the participant's head at eye level, for more information see the protocol by González-Fernández et al., 2022.

2.4. Data collection

The 2 evaluations were carried out at the same time and on the same day of the week, taking into account a rest without competition for at least 48 h to avoid the effects of muscle fatigue. i) First day from 9:30 to 11:00 a.m.: Anthropometric measures, Hear Rate Variability, Cognitive task (The order of presentation of the tasks was counterbalanced across participants); ii) Second day from 7:30 to 9:30 p.m.: Countermovement Jump and Yo-Yo Intermittent Recovery Test. Heart Rate Variability, the Cognitive task, and Anthropometric measurements were performed in a private room with a stable temperature of 22 °C and relative humidity of 52 %. The Countermovement Jump and Yo-Yo Intermittent Recovery Test were performed on a synthetic turf field with a mean temperature of 17 °C and relative humidity of 60–70 %. No windy or rainy conditions occurred in the assessment.

2.5. First day of assessment

At the beginning of each assessment, anthropometric measures (Weight, Body Mass Index, Lean Mass, and Muscle) were recorded, at the same time and on the same day of the week. Players were asked to remove their shoes and other accessories that could influence the assessment. In addition, players also had to be in a vertical and immobile position, with arms extended along the body, and looking straight ahead in an upright position. The measures were taken in the morning (9:00 a.m.) at the beginning of the pre-season period (July) and at the end of the pre-season (September).

After the anthropometric measures, HRV metrics were taken, and each participant rested for 5 min in a supine position to record the baseline HRV, and after another 5 min in a sitting position. Both conditions were measured in a dimly illuminated room, at a comfortable temperature (22 °C and relative humidity of 52 %), and isolated from external noise. Participants were encouraged to stay as relaxed as possible during this procedure. The Polar HR monitor was attached around the chest of the participant upon arrival at the experimental site and the values were recorded in a Polar RS800 CX and processed via Polar-specific software (Polar® ProTrainer 5). Following the indications of Radespiel-Tröger et al. [33], data were collected at a sampling rate of 1000 Hz, providing a temporal resolution of 1 ms for each RR interval. Consequently, each participant's data (RR interval file) were transferred and analysed by means of the Kubios HRV Analysis Software version 3.5.0 [34]. RR intervals were replaced by conventional spline interpolation [35]. In addition, we corrected and deleted low frequency baseline components [36]. We analysed the HRV within the time domain: the mean R–R interval, standard deviation of R–R interval (SDNN) and the root-mean-square difference of successive normal R–R intervals (rMSSD) and the average length of a set of nucleotide sequences (NN50).

2.6. Cognitive measurement

2.6.1. Psychomotor Vigilance Task (PVT)

The PVT consisted of presenting a grey screen with a chronometer that appeared at the centre of the screen and was used to control the presentation of stimuli and the collection of data, which began to be completed at the speed of a real stopwatch and that could be presented on the screen after a random time interval that ranged between 2.000 ms and 10.000 ms. The participants had to press the centre of the device as quickly as possible when the chronometer began to advance. The task included a single block lasting 10 min. The

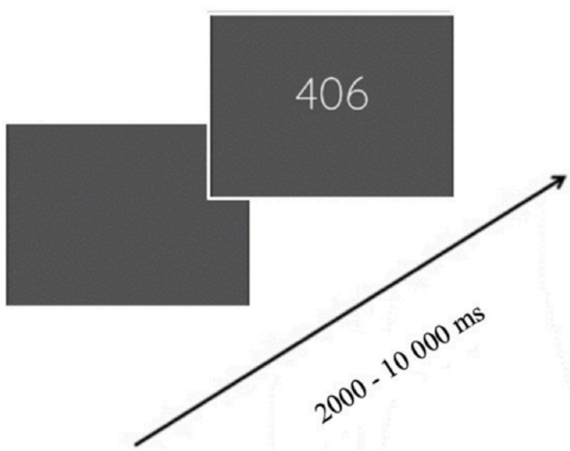

Fig. 1. Example of one trial of the PVT.

exact number of trials by each participant depended on the latency of the individual's response. All subjects completed the same number of PVT (Fig. 1).

2.6.2. Sustained attention to respond task (SART)

The SART, as in the original go no-go task developed by Robertson et al., 2012 [37] demands that participants respond as quickly as possible to single digits randomly ranging between 1 and 9 (go trial), unless the digit 3 is presented, to which they have to inhibit their response (no-go trial). A blank screen was presented for 200 ms followed by a digit that remained on the screen during 600 ms or until the participant's response. Subsequently, the fixation point (X) appeared in the centre of the screen. The task was composed of 100 go trials and 20 no-go trials leading to a no-go proportion of .17 (Fig. 2).

2.7. Second day of assessment

2.7.1. Countermovement jump

The Chronojump-Boscosystem® jumping platform (Barcelona, Spain) developed by de Blas et al. (2012) [38] was used for the evaluation of the CMJ. It has high reliability for measuring jump height ($\alpha = 0.891$). This system was connected to a MacBook Pro (macOs Monterey 12.3). The values were analysed with a chronograph and recorded by Chronojump version 2.2.1. After warming up, players performed the CMJ test three times on a contact platform, with 20 s of recovery between attempts to minimize the effect of fatigue. The average between jumps (in cm) was considered the final result. Players were also instructed to keep their hands on their hips during the CMJ and to land with their legs extended with maximum foot plantar flexion. If any of these requirements were not met, the jump was repeated.

2.7.2. Yo-Yo intermittent recovery test – level 1

The Yo-Yo IR1 test consisted of repeated 20-m runs back and forth between two markers with a progressive increase in speed, regulated by an audio player. Between each 40-m run, the athlete recovered with 10 s of jogging (shuttle runs of 2×5 m). Yo-Yo Level 1 starts at 10 km/h and Level 2 at 13 km/h, with both levels progressively increasing in speed throughout the test. The test was completed when the athlete reached voluntary exhaustion or failed to maintain her running pace in synchrony with the audio recording. The number of completed levels and shuttles and the total distance covered were recorded at the end of the test. The total distance (metres) was extracted as the outcome. $VO2_{max}$ was estimated with the following equation: Yo-Yo IR1 test: $VO2_{max}$ (mL/min/kg) = IR1 distance (m) $\times$ 0.0084 + 36.4 [39].

2.8. Statistical procedures

The Kolmogorov-Smirnov test was analysed, resulting in a normal distribution. Descriptive statistics were carried out for each variable (Table 2). Regarding changes during the preseason, a paired samples *t*-test was used to determine differences as a repeated measures analysis (Assessment 1 – Assessment 2). Cohen's d was the indicator of effect size. To interpret the magnitude of the effect size, we adopted the following criteria: $d = 0.20$, small; $d = 0.50$, medium; and $d = 0.80$, large. A Pearson correlation coefficient *r* was used to examine the relationship between anthropometric measures (Weight, Body Mass Index, Lean Mass, and Muscle), physical fitness (CMJ, Yo-Yo test), cognitive measures (PVT and SART) and HRV measures (Mean RR, RMSDD and NN50). The significance level was set at 5 % ($p < .05$). The effect size (*d*) was calculated through Cohen's *d* [40]. The interpretation of the d regardless of the sign, followed the scale: very small (0.01), small (0.20), medium (0.50), large (0.80), very large (1.20), huge (2.0) as initially suggested by Cohen and expanded by Savilowky et al. [41] Multiple regression analysis was used to model the prediction of anthropometric

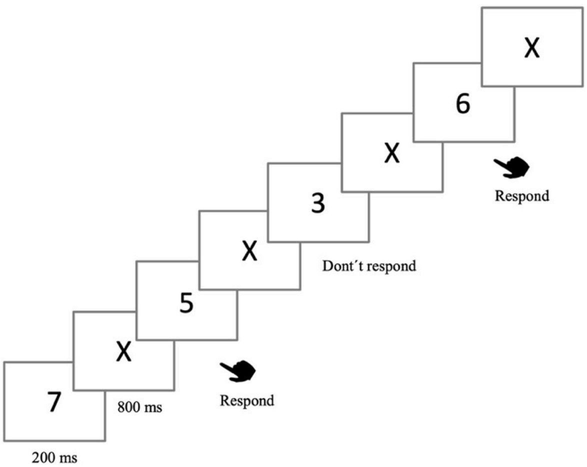

Fig. 2. Sustained Attention to Response Task (SART) paradigm.

Table 2
Anthropometric measurement and fitness variables at the two assessments (Mean ± SD).

Women soccer players (n = 16)				
	Asssesment 1	Assessment 2	UCI | CI | LCI (95 %)	*t*-Test | Cohen d
Anthropometric measurement				
Height (cm)	166.07 ± 6.97	166.29 ± 6.88	168.80 | 3.62 | 162.56	$p = .47$ |$d = -0.03$
Weight (kg)	61.59 ± 9.03	62.59 ± 9.30	66.80| 4.71 | 57.38	$p = .30$ |$d = -0.11$
Body Mass Index (%)	22.20 ± 2.15	22.57 ± 2.44	23.54 | 1.15 | 21.23	$p = .31$ |$d = -0.16$
Lean Mass (%)	29.25 ± 4.01	30.75 ± 3.99	31.97 | 1.97 | 28.03	$p = .05$* |$d = -0.38$
Muscle (%)	22.29 ± 2.08	22.62 ± 2.33	23.46 | 1.01 | 21.45	$p = .31$ |$d = -0.15$
Countermovement jump				
CMJ (cm)	23.76 ± 2.38	25.52 ± 3.37	30.94 | 0.86 | 29.22	$p = .01$* |$d = -0.61$
Yo-Yo Intermittent Recovery Test. Level 1				
Distance (m)	808.00 ± 154.60	890.67 ± 160.33	712.04 | 42.35 | 424.93	$p = .001$** |$d = -0.52$
VO2max (mL·kg^{-1} min^{-1})	43.19 ± 1.30	43.88 ± 1.35	44.59 | 0.71 |43.18	$p = .001$** |$d = -0.52$

Note: UCI: Upper confidence interval; CI: Confidence interval; LCI: Lower confidence interval; CMJ: Countermovement jump.
* Denotes significance at $p < .05$, and ** denotes significance at $p < .01$.

measures, physical fitness, cognitive and HRV measures. This regression analysis examined all variables separately. Statistical analysis was performed using Statistica software (version 13.3; Statsoft, Inc., Tulsa, OK, USA).

3. Results

Descriptive statistics were calculated for each variable (Table 2).

3.1. Anthropometric measures

A paired measures *t*-test with participants' mean anthropometric measures (i) Height ii) Weight, iii) Body Mass Index (%) and Muscle did not reveal significant effects, $p = .47$, $d = 0.09$, $p = .30$, $d = -0.11$, $p = .31$, $d = -0.16$ and $p = .31$, $d = -0.15$, respectively. However, another *t*-test with Lean Mass (%) revealed significant effects, $p = .05$*|$d = -0.38$ (Fig. 3).

3.2. Physical fitness

A new paired measures *t*-test with participants' mean physical fitness values of Countermovement jumps and Yo-yo Intermittent Recovery Test Level 1 [(i) distance and ii) $V02_{max}$ (mL·kg^{-1} min^{-1})] revealed a significant effect, $p = .01$* |$d = -0.61$, $p = .001$** |$d =$

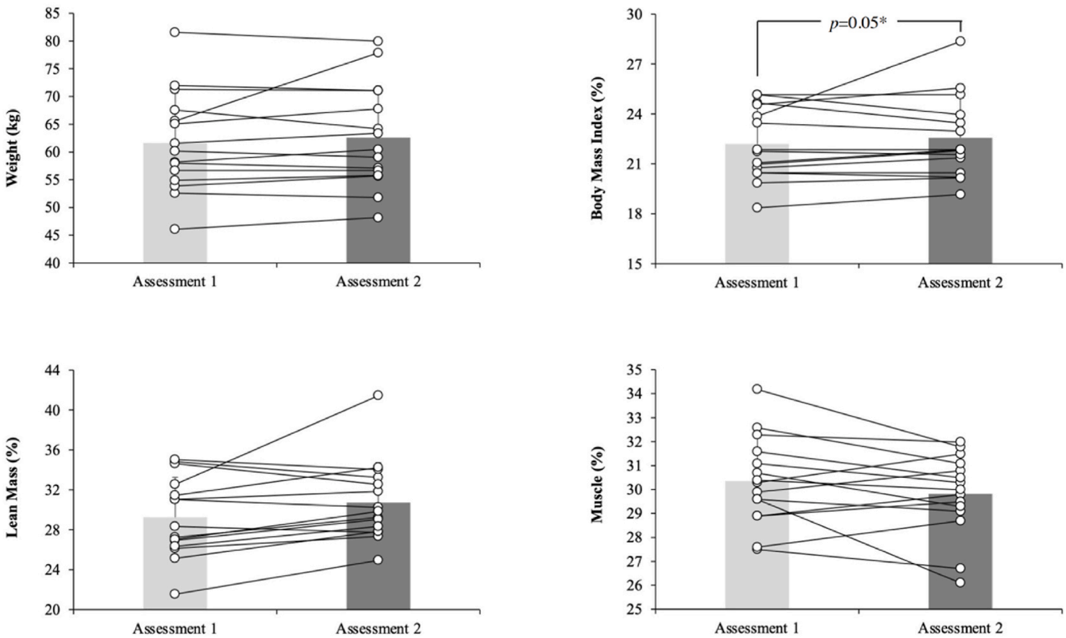

Fig. 3. Anthropometric measures (Weight, Body Mass Index, Lean Mass and Muscle %) in assessment 1 and assessment 2.

−0.52 and $p = .001^{**}$ $|d = -0.52$, respectively (Fig. 4).

3.3. HRV measures

A paired measures *t*-test with participants' mean HRV (Mean RR, RMSSD and NN50) was performed and revealed a significant effect in RMSSD and NN50 in both positions, RMSSD [recumbent ($p = .01$, $d = -0.73$) and sitting ($p = .04$, $d = -0.52$)] and NN50 [recumbent ($p = .05$, $d = -0.69$) and sitting ($p = .05$, $d = -0.70$)]. However, mean HR [recumbent ($p = .91$, $d = 0.03$) and sitting ($p = .54$, $d = -0.13$)], mean HR [recumbent ($p = .78$, $d = 0.11$) and sitting ($p = .87$, $d = 0.06$)], did not reveal significant effects. See Table 3.

3.4. Cognitive measures: PVT and SART

PVT: A paired measures *t*-test with participants' mean RT revealed a significant effect of Assessment ($p = .02$, $d = 0.42$), with shorter RTs in Assessment 2.

SART. A paired measures *t*-test with participants' mean ACC GO and ACC NO GO revealed a significant effect of Assessment ($p = .01$, $d = -0.89$, $p = .02$, $d = -0.57$). However, a paired measures *t*-test with participants' mean RT GO did not reveal a significant effect of Assessment ($p = .08$, $d = 0.37$; Table 4).

Correlation analyses were performed between anthropometric measures and physical fitness and cognitive measures and HRV variables (Table 5). The dataset showed a negative moderate correlation between W, BMI and LM and HRV. Mean RR Sitting, r = -0.66, p = .007, r = -0.60, p = .01, r = -0.56, p = .02, respectively. In addition, the dataset revealed a positive moderate correlation between L and HRV. Mean RR Sitting, r = 0.53, p = .04. Another negative moderate correlation was found between W and HRV. RMSDD Sitting, r = -0.50, p = .05. Last, a new negative large correlation was found between W and BMI and HRV. NN50 Sitting, r = -0.83, p = .001, r = -0.80, p = .001. However, a negative moderate correlation was found between LM and HRV. NN50 Sitting, r = -0.53, p = .04.

Correlation analyses were performed between physical fitness and anthropometric and cognitive measures and HRV variables (Table 6). The dataset showed a positive moderate correlation between CMJ and HRV Mean RR Recumbent, r = -0.66, p = .007 and a negative moderate correlation between Yo-Yo test and HRV Mean RR Recumbent, r = -0.60, p = .01.

Correlation analyses were performed between cognitive measures and physical fitness and anthropometric measures and HRV variables. However, no significant correlation was found between variables.

Finally, a multiple regression analysis (Table 7) was performed to verify which variable (agreement with the correlation analysis) could be used to best explain the importance of the pre-season in women soccer player. The dataset revealed more significance between weight and NN50 Sitting ($R^2 = 0.69$, $p = .001$), BMI and NN50 Sitting ($R^2 = 0.65$, $p = .001$), weight and mean RR. Sit ($R^2 = 0.33$, $p = .01$), BMI and mean RR. Sitting ($R^2 = 0.33$, $p = .002$), lean mass and mean RR. Sit ($R^2 = 0.32$, $p = .03$) and NN50 Sitting ($R^2 = 0.28$, $p = .04$), Muscle and mean RR. Sitting ($R^2 = 0.29$, $p = .04$) and between CMJ and mean RR. Rec ($R^2 = 0.27$, $p = .05$).

4. Discussion

The current research revealed that lean mass significantly improved after the period of observation, while no other significant changes in body anthropometry were observed. Additionally, the countermovement jump, and aerobic power were also significantly improved. The RMSSD and NN50 significantly increased after the period of observation. The reaction time also significantly improved after the period of observation. Correlations performed between measures revealed that smaller body mass and body mass index were largely associated with greater NN50. Additionally, greater CMJ and aerobic fitness were associated with greater heart rate variability. No significant correlations were found between cognitive performance and physical fitness.

Seasonal variations are expected in women soccer players [42]. The regular detraining occurring in the off-season is a basis for expected improvements in the physical fitness of soccer players [43]. The detrimental effects of the off-season on soccer players are well established, as well as the return to better levels after the pre-season which typically emphasises training volume and a progressive increase in intensity [44]. One of the components massively affected by the detraining period is body composition [44]. Previous research confirms that even in players performing off-season individualised training programmes, body composition (e.g., fat mass, lean mass) is affected [44]. Thus, an improvement is expected when returning to regular training practice. This was confirmed by our

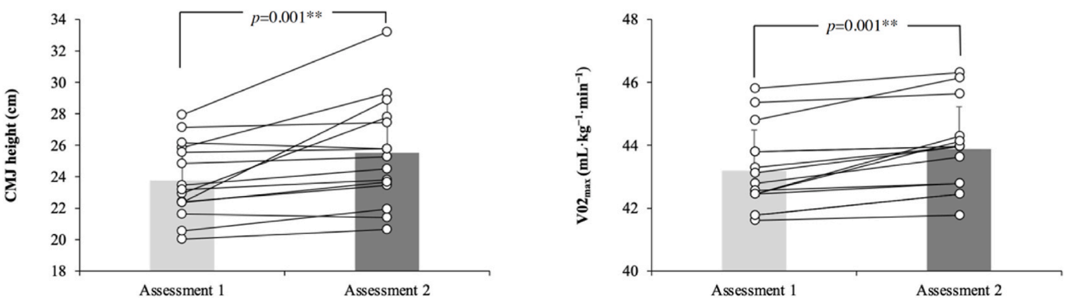

Fig. 4. Physical fitness measures (Countermovement Jumps and Yo-yo Intermittent Recovery Test. Level 1) in assessment 1 and assessment 2.

Table 3
HRV measures at the two assessments in two moments (Mean ± SD).

	Mean HR (1 min)				Mean RR (ms)				RMSSD				NN50			
	A1		A2		A1		A2		A1		A2		A1		A2	
WSP	Rec	Sit	Rec	Sit	Rec	Sit	Rec	Sit	Rec	Sit	Rec	Sit	Rec	Sit	Rec	Sit
1	69.65	79.89	92.38	97.08	871.61	763.66	653.01	624.57	71.60	32.31	90.91	28.05	241.00	193.00	209.00	70.00
2	84.81	92.42	73.83	86.22	715.89	654.66	822.45	705.55	57.31	43.02	90.43	47.69	153.00	117.00	406.00	189.00
3	81.13	80.77	73.74	74.52	741.89	747.03	823.16	810.69	37.34	38.73	86.21	54.39	112.00	92.00	372.00	294.00
5	63.40	73.77	58.90	62.26	956.83	828.47	696.72	669.22	70.38	76.07	94.41	99.46	182.00	190.00	317.00	358.00
6	87.93	84.54	74.23	87.55	577.62	598.61	761.24	664.62	22.75	32.64	46.42	60.85	0.00	72.00	229.00	259.00
7	79.86	79.88	65.23	71.72	711.65	696.48	765.17	719.13	15.57	21.51	60.01	62.11	2.00	15.00	275.00	263.00
8	96.17	103.93	79.30	90.39	726.53	581.07	666.59	668.59	34.49	26.72	76.44	36.92	68.00	38.00	300.00	98.00
9	72.74	76.00	69.65	79.89	835.50	796.95	748.89	523.37	47.81	83.73	61.13	64.67	261.00	158.00	209.00	38.00
10	80.96	84.14	90.04	88.59	743.27	715.47	667.95	680.12	27.59	22.92	38.03	38.13	45.00	27.00	10.00	14.00
11	41.12	38.98	63.91	62.96	647.02	589.83	939.88	959.63	51.46	22.86	57.63	34.61	190.00	26.00	21.00	80.00
12	70.33	75.03	68.42	73.21	859.58	804.93	818.06	843.13	54.51	49.32	68.43	74.71	139.00	159.00	294.00	344.00
13	68.96	66.10	67.20	70.01	873.65	912.33	897.33	877.69	44.14	42.26	46.56	51.92	134.00	104.00	208.00	266.00
14	84.79	80.76	84.81	84.11	709.95	745.39	709.64	715.54	22.80	31.41	32.16	45.48	20.00	67.00	19.00	42.00
15	72.67	80.18	84.34	88.96	832.56	756.65	715.79	679.45	86.36	53.06	41.81	33.26	285.00	178.00	130.00	117.00
16	67.82	69.41	70.89	73.07	889.66	871.14	852.75	828.28	73.49	56.67	57.00	48.37	279.00	214.00	288.00	223.00
Mean	74.82	77.72	74.46	79.37	779.55	737.51	769.24	731.30	47.84	42.22	63.17	52.04	140.73	110.00	219.13	177.00
SD	12.91	14.03	9.85	10.55	103.72	100.21	87.46	111.80	21.33	18.86	20.55	18.59	99.17	68.29	125.15	117.55

Note: FSP: Women Soccer Players; Rec: Recumbent; A1: Assessment 1; A2: Assessment 2.

Table 4
Cognitive measures: PVT and SART values at the two assessments (Mean ± SD).

Women soccer players (n = 16)				
	Assessment 1	Assessment 2	UCI | CI | LCI (95 %)	*t*-Test | Cohen d
PVT	383.09 ± 35.99	367.90 ± 37.06	393.67 | 18.17 | 357.33	$p = .21^{*} \mid d = .42$
SART ACC GO	0.96 ± 0.04	0.99 ± 0.02	0.96 | 0.01 | 0.98	$p = .01^{*} \mid d = -0.89$
SART ACC NO GO	0.50 ± 0.16	0.69 ± 0.17	0.47 | 0.08 | 0.63	$p = .02^{**} \mid d = -0.57$
SART RT GO	328.96 ± 60.33	309.83 ± 42.65	294.11 | 25.29 | 344.68	$p = .08 \mid d = 0.37$

Note: UCI: Upper confidence interval; CI: Confidence interval; LCI: Lower confidence interval. * Denotes significance at $p < .05$, and ** Denotes significance at $p < .01$.

Table 5
Pearson's correlation coefficient between anthropometric measures and physical fitness and cognitive measures and HRV variables. *Significance at $p < .05$. **Significance at $p < .01$.

	Physical Fitness		HRV. Mean RR		HRV. RMSDD		HRV. NN50		Cognitive Measures			
	CMJ	Yo-Yo test	Rec	Sit	Rec	Sit	Rec	Sit	PVT	ACC Go	ACC No Go	RT Go
W	r = −.16 *p* = .54	r = −.10 *p* = .71	r = −.34 *p* = .21	r = −.66 *p* = .007*	r = −.15 *p* = .58	r = −.50 *p* = .05*	r = −.03 *p* = .89	r = −.83 *p* = .001**	r = .16 *p* = .55	r = −.11 *p* = .67	r = .09 *p* = .73	r = .20 *p* = .47
BMI	r = −.08 *p* = .75	r = −.06 *p* = .82	r = −.30 *p* = .26	r = −.60 *p* = .01*	r = −.11 *p* = .68	r = −.46 *p* = .07	r = −.09 *p* = .74	r = −.80 *p* = .001**	r = .09 *p* = .73	r = −.12 *p* = .66	r = .09 *p* = .72	r = .17 *p* = .53
LM	r = .01 *p* = .99	r = −.14 *p* = .60	r = −.38 *p* = .21	r = −.56 *p* = .02*	r = −.11 *p* = .67	r = −.31 *p* = .25	r = −.08 *p* = .75	r = −.53 *p* = .04*	r = .09 *p* = .72	r = −.09 *p* = .74	r = −.26 *p* = .33	r = −.02 *p* = .94
M	r = −.14 *p* = .60	r = .15 *p* = .58	r = .29 *p* = .29	r = .53 *p* = .04*	r = .12 *p* = .65	r = .31 *p* = .25	r = .10 *p* = .71	r = .48 *p* = .07	r = −10 *p* = .70	r = .09 *p* = .74	r = .25 *p* = .35	r = −.11 *p* = .68

HRV: Heart Rate Variability; W: Weight; BMI: Body Mass Index; LM: Lean Mass; M: Muscle: CMJ: Countermovement Jump; Rec: Recumbent.

Table 6
Pearson's correlation coefficient between physical fitness and anthropometric and cognitive measures and HRV variables. *Significance at $p < .05$. **Significance at $p < .01$.

	Anthropometric measures				HRV. Mean RR		HRV. RMSDD		HRV. NN50		Cognitive Measures			
	W	BMI	LM	M	Rec	Sit	Rec	Sit	Rec	Sit	PVT	ACC Go	ACC No Go	RT Go
CMJ	r = −.16 *p* = .54	r = −.08 *p* = .75	r = .01 *p* = .99	r = −.14 *p* = .60	r = .51 *p* = .05*	r = .48 *p* = .07	r = −16 *p* = .55	r = .34 *p* = .20	r = −.50 *p* = .06	r = .35 *p* = .06	r = −.12 *p* = .19	r = .09 *p* = .72	r = −.29 *p* = .29	r = .48 *p* = .06
Yo-Yo test	r = −.10 *p* = .71	r = −.06 *p* = .82	r = −.14 *p* = .60	r = .15 *p* = .58	r = .45 *p* = .09	r = −.60 *p* = .01*	r = .07 *p* = .79	r = .12 *p* = .65	r = −.06 *p* = .81	r = −.06 *p* = .81	r = .14 *p* = .59	r = .34 *p* = .21	r = .07 *p* = .78	r = .03 *p* = .90

HRV: Heart Rate Variability; W: Weight; BMI: Body Mass Index; LM: Lean Mass; M: Muscle: CMJ: Countermovement Jump; Rec: Recumbent.

Table 7
Values of regression analysis explaining the relevance between variables.

		R	R^2	Adjusted R^2	F	P	SE
Weight	**Mean RR. Sitting**	0.66	0.44	0.40	10.21	0.01*	15.78
	NN50. Sitting	0.83	0.69	0.67	28.82	0.001**	65.93
BMI	**Mean RR. Sitting**	0.60	0.36	0.31	7.33	0.02*	16.86
	NN50. Sitting	0.81	0.65	0.62	23.98	0.001**	70.11
Lean Mass	**Mean RR. Sitting**	0.57	0.32	0.27	6.20	0.03*	17.35
	NN50. Sitting	0.53	0.28	0.23	5.14	0.04*	100.10
Muscle	**Mean RR. Sitting**	0.54	0.29	0.23	5.24	0.04*	17.80
CMJ	**Mean RR. Rec**	0.52	0.27	0.21	4.77	0.05*	16.66

results which showed that after an 8-week pre-season period, lean mass was significantly improved while no other significant changes in body mass were observed. Lean mass is a product of subtraction of fat mass from body mass, which suggests that the pre-season has a beneficial effect in reducing fat mass [45]. This can be expected since traditionally training in pre-season emphasises training volume with a moderate-to-high intensity which increases metabolic stress, necessarily affecting fat mass by reducing energy availability [46].

The results are also in line with previous studies suggesting improvements in lean mass after the pre-season period in soccer [47].

A significant improvement was also observed in the physical fitness levels of players, namely increased lower-limb power (estimated using the CMJ) by 7.4 % and aerobic fitness (measured by distance covered at YYIRT) by 10.2 %. These results can be confirmed by previous studies indicating a progressive increase in lower-limb power and aerobic fitness after the pre-season [48]. The explanation for the improvements can be found in two main factors: detraining occurring before baseline assessment and the effects of retraining in the pre-season. Usually, lower-limb power and aerobic fitness can be negatively influenced by detraining in the off-season [49]. Although some type of personalised training in the off-season may mitigate the decrements, both levels are affected by the decrease in training volume and intensity [49]. Thus, this justifies a window of opportunity for trainability and for enhancing these levels in the pre-season [50]. Most of the work performed in soccer training stresses the aerobic metabolism (namely progressive intensification) which is associated with improvements in aerobic power and maximal aerobic speed [51]. However, since reactive force and strength are also part of back-to-training programmes, it is also expected to observe improvements in CMJ, namely because it is a determinant and predictor of performance in high-intensity locomotor activities such as sprinting [52].

In the current research it was observed that both RMSSD and NN50 were significantly increased after the training period (8-week). This is associated with the training load imposed which was previously observed in a study conducted with high level women soccer players [53,54]. Our results are also in line with a previous study which reported that the lower heart rate variability levels occur at the start of pre-season and at the end of the season, while during the season it is stable in the higher levels [55]. Although heart rate variability is context-dependent, it is expected that an appropriate adaptation to the progressive load imposed during the pre-season can enhance it [56]. In fact, the impact of the result of soccer matches could be considered as a key factor when programming training load in women soccer players [57]. Regarding the additional analysis that was performed in the current research, it was observed that heart rate variability was meaningfully correlated with body composition and better physical fitness parameters. See Mattos et al., 2022 for more information [58]. Indeed, recent studies confirm this strong relationship between greater heart rate variability and physical fitness [59]. This can be a consequence of the fact that, normally, progressive increments in heart rate variability explain physical adaptations and also suggest good adaptations to the training stimulus [60]. Thus, improvements in physical fitness and body composition can also explain the improvements observed in heart rate variability [61].

The analysis to reaction time revealed significant improvements in the psychomotor vigilance test, as well as in the SART test. The ability to recognise visual stimuli and immediately respond to them is something necessarily connected with soccer practice Players are required in soccer to respond to situations and being quicker in detecting and reacting may produce a difference in the response time [62,63]. Since experience is related to reaction time and anticipatory skills [62], it is expected that exposure to a higher volume of visual search, stimulus and decisions favour soccer players coming from detraining [64].

The current study presents some limitations. One of the limitations is the absence of a control group which does not allow for identifying the cause of changes. To increase the level of consistency of these results, future researchers are urged to incorporate a control group to compare the effect of the pre-season on other teams of similar level of expertise. However, an improvement in cognitive, physical, anthropometric and physiological levels has been described in this study, which allows comparison with the initial states of the soccer players. In this case, it would be of great interest to know how they finished the season and see the detraining produced in the rest period. Moreover, training load and type of training process were not monitored which constitutes another study limitation. Future studies should extend the sample recruited, namely increasing the number of participating teams and splitting the sample forming control groups, to understand if those training more or less (e.g., using training load quantification as an example) can be associated with more or fewer improvements. Moreover, it is also important to control the off-season process namely understanding the trainability level at which players reach the pre-season. Despite the limitations, this study is one of the few analysing the evolution of cognitive performance during the pre-season in women soccer players which makes it unique.

5. Conclusion

This study revealed that the pre-season induced significant improvements in the body composition, physical fitness, and cognitive performance of women soccer players. However, the results should not be generalised since no control group was analysed and no identification of cause was identified. Additionally, it was observed that heart rate variability was significantly associated with body composition and physical aptitude during the pre-season in women soccer players.

Data availability statement

Data will be made available on request.

Funding/Support statement

This research was funded with charge to the aid 10/UPB/23 granted by the Consejo Superior de Deportes, Ministerio de Educación, Cultura y Deporte, Gobierno de España.

CRediT authorship contribution statement

Francisco Tomás González-Fernández: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Ana Filipa Silva:** Writing – original draft, Visualization, Project administration, Investigation, Conceptualization. **Alfonso Castillo Rodriguez:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Wanesa Onetti-Onetti:** Writing – review & editing, Writing – original draft, Resources. **Filipe Manuel Clemente:** Writing – original draft, Supervision, Software, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

All authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank all female soccer players who participated in the present study.

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