ORIGINAL

MULTIVARIATE TRAINING PLANNING MODEL IN PROFESSIONAL SOCCER

MODELO MULTIVARIABLE PARA LA PLANIFICACIÓN DEL ENTRENAMIENTO EN FÚTBOL PROFESIONAL

Chena Sinovas, M.[1]; Morcillo Losa, J.A.[2]; Rodríguez Hernández, M.L.[1]; Zapardiel, J.C.[1]

[1] Doctores en Ciencias de la Actividad Física y del Deporte. Facultad de Medicina y Ciencias de la Salud. Universidad de Alcalá (España) marcoschenapf@hotmail.com, mluisa.rodriguez@uah.es, carlos.zapardiel@uah.es

[2] Doctor en Ciencias de la Actividad Física y del Deporte. Facultad de Humanidades y Ciencias de la Educación. Universidad de Jaén (España) jamlosa@ujaen.es

ABSTRACT

The aim of this study was to describe a multivariable training planning model for weekly monitoring and its periodization in relation to the dynamic competitive profile. Twenty-two professional soccer players participated in this study. Thirty competitive microcycles were analyzed. Thirty competitive microcycles were recorded individually in all training sessions and competition matches through a GPS device. The results showed a loading phase with values close to those achieved in competition, but with differentiated stimuli on consecutive days, and another phase of load reduction in the form of tapering prior to competition. The weekly accumulated load showed little variability between the microcycles; an average of 0.6% was observed. Dynamic load management presented an A: C ratio that ranged from 0.89-1.13. It can be concluded that the multivariate model for planning weekly training is an effective method to monitor training load in relation to performance profile.

KEY WORDS: GPS, performance, training load, acute load, chronic load.

RESUMEN

El objetivo de este estudio fue describir un modelo multivariable de planificación del entrenamiento para la monitorización semanal y su periodización en relación con el perfil dinámico competitivo. Veintidós futbolistas profesionales participaron este estudio. Se analizaron 30 microciclos competitivos donde se registró individualmente todas las sesiones de entrenamiento y partidos de competición mediante GPS. Los resultados mostraron una fase de carga con valores cercanos a los alcanzados en competición, pero con estímulos diferenciados en días consecutivos, y otra fase de reducción de la carga en forma de *tapering* previa a la competición. La carga acumulada semanalmente mostró poca variabilidad entre los microciclos, observándose un promedio de 0.6%. La gestión dinámica de la carga presentó un ratio A:C que osciló entre 0.89-1.13. El modelo multivariable para la planificación del entrenamiento semanal es un método eficaz para monitorizar la carga del entrenamiento en relación con el perfil de rendimiento.

PALABRAS CLAVE: GPS, rendimiento, carga de entrenamiento, carga aguda, carga crónica.

1. INTRODUCTION

The evolving nature of soccer in relation to the increase in physical, technical and tactical demands has led to the requirement for a scientific background of those parameters concerning training structure and planning[1,2]. Despite the fact that the physical demands of the competition and the functional characteristics of the teams and their players are highly known[1,3], the contextual variables of the competition[4] that influence the conditional performance of athletes, high multifactorial variability and complexity to determine sports success in soccer have led coaches to challenge training principles through planning and methodology, searching for performance improvement without exceeding the limits of physiological tolerance of players[2].

Training control has been one of the most studied research topics in recent years[2]. Control and quantification of training loads should be understood as the process through which the necessary information to generate knowledge is recorded. This knowledge should allow to make decisions to prescribe individualized or collective training programmes, with which to maximize the adaptations in athletes while minimizing the cumulative effects of fatigue[5].

Inappropriate training loads relate to an increase in injury rate, a decrease in the individual physical ability and a reduction of collective performance[6-9]. The use of Global Positioning Systems (GPS) to control training loads in professional soccer players has become increasingly frequent[5,9,10]. Although this tool allows to quantify the external load to which the athlete is subjected in training, strong correlations with other methods of quantification of internal load based on session-RPE have been found[11-13].

The variability of the training load throughout the competitive week must guarantee the optimization of fitness in athletes to perform, managing the stimulation and tapering processes in a balanced way[3,5,12]. Therefore, the distribution of the variables *load intensity* and *load volume* along the competitive microcycle must provide the sufficient stimulus to provoke or maintain the corresponding specific adaptations, offering a tapering of the load prior to competition used to fight fatigue without provoking a loss of the adaptations achieved[5,10,14].

Periodization provides a framework for planned and systematic variation of training parameters with the aim of optimizing training adaptations specific to a particular sport throughout the competition period[15]. Recent researches have examined the accumulated working load in a week (acute load) in relation to the average load over the past 4 weeks (chronic load) as a reference criterion to control the training load in team sports[6,7,9]. Acute load has been considered as an indicator of fatigue induced through training and competition, while chronic load represents fitness in athletes through tendency[6]. In accordance with this criterion, training planning seeks to establish an optimal balance relationship between fatigue and fitness in athletes in order to withstand fatigue, with the goal of making sense of the periodization of planned stimuli in the process of training[6-9].

The present study aimed at describing a multivariate planning model for monitoring weekly training and its periodization in relation to the competitive dynamic profile (CDP) of a professional soccer team.

2. MATERIAL AND METHODS

2.1. Participans

Twenty-two soccer players belonging to a professional soccer team in the Spanish league participated in this study. The average of the age, height, weight, percentage of body fat (Harpenden caliper), VO_{2max} (Yo-Yo Intermittent Recovery Test level 2) and summation of 6 body folds (Harpenden caliper) throughout the study were 26.36 ± 4.0 years, 179 ± 5.8 cm, 74.76 ± 8.0 kg, 9.88 ± 8.0%, 54.3 ± 5.1 ml · kg^{-1}, 39.67 ± 13.6 mm, respectively.

This study registered 30 official competition matches and 167 training sessions distributed according to the calendar in 30 competitive microcycles of identical structure.

In order to guarantee the reliability and the validity of this study, the registered data belonged to the players who completed each of the training sessions successfully, removing goalkeepers data and the data obtained from players who followed adapted or tailored training to manage fatigue, to improve individual performance or due to injury[5,16]. The compilation of competitive data was carried out taking into account just the footballers who played at least 80 minutes in the match[2,5]. The preseason (6 weeks) was the period of familiarization of the athletes with the GPS devices.

No microcycle presented more than one session a day with the whole team, and all training sessions took place in the morning and at the same time. The footballers maintained the same habits throughout the study.

Players received detailed information about the objective and procedure for the study before the investigation. All the participants signed a consent form and received a detailed report on the confidentiality of data in accordance with Organic Law 15/1999, dated 13 December (BOE 12-14-1999). The club involved approved the investigation before beginning the assessment. The study is certified by the Ethics Committee at the University of Alcalá and all the data were processed according to the Declaration of Helsinki.

2.2. Procedure

Player movement time was recorded individually in all training sessions and competition matches using a 10 Hz GPS device (GPEXE©. Italy) [14]. To avoid variability, each player was always equipped with the same GPS device, which was located between the shoulder blades with the help of a special vest, using the specialized analysis software GPEXE© to download data.

The analyzed microcycles consisted of one competition match and five training sessions before the aforementioned match with an average duration of 56.2

minutes of active time. The sessions (MD- *) were named according to the number of days away from the competitive match (MD). Only the following training sessions were considered: MD-4, MD-3, MD-2, MD-1. The MD-4 session was preceded by a rest day. Other data related to the pre-MD-4 sessions (post-match recovery sessions) or pre-MD (sessions with players who did not participate in the match) were not taken into account due to insufficient training content[5].

The multivariate planning model registered four volume indicators (total distance covered, number of accelerations, number of decelerations and high-speed running) and four intensity indicators (equivalent distance index, metabolic power, relative distance covered and relative high-speed running). These criteria are enough to provide relevant information regarding the load in training and competition sessions[9,14]. Given the nature of the monitored variables, we chose those that provided information about the mechanical, neuromuscular and metabolic loads in sportspeople[13,17] (see Table 1).

Table 1: Volume and intensity variables

Volume	Intensity
Total distance covered (TDC) (m)	[d] Equivalent distance index (EDI) (%)
[a] Number of Acceleration (Ac) (m/s^2)	[e] Metabolic power (MP) (W/Kg)
[b] Number of Deceleration (Dc) (m/s^2)	Relative distance covered (TDC/time) (m/min)
[c] High-speed running (HSR) (m)	Relative high-speed running (HSR/time) (m/min)

[a] *Number of events >2.50 m/s^2*

[b] *Number of events <-2.50 m/s^2*

[c] *Total distance covered >21 km/h*

[d] *Ratio between ED (ED)=Equivalent Distance: represents the distance that the athlete would have covered at constant speed by using the total energy consumed during a training session) and the TDC*

[e] *Energy expenditure per unit of time, above resting (speed · energy cost)*

The methodology used to monitor training load in relation to competition consisted of individually comparing the data recorded by the GPS in the training and match sessions with the player's CDP. The CDP is the competitive dynamic profile of footballers and varies throughout the season. In this study, the CDP was calculated with the average data obtained in the last four matches in which the player participated for more than 80 minutes. Each player was analysed individually, whereas team monitoring was obtained through the average data from all the players studied (see Figure 1). The methodology used to describe training periodization consisted of a double criterion: relating the cumulative load of a microcycle (acute load) with respect to the cumulative load of the previous microcycle (% M / M) and relating the acute load with respect to the chronic working load (ratio A: C).

The content of the training was not modified in any way by the researchers.
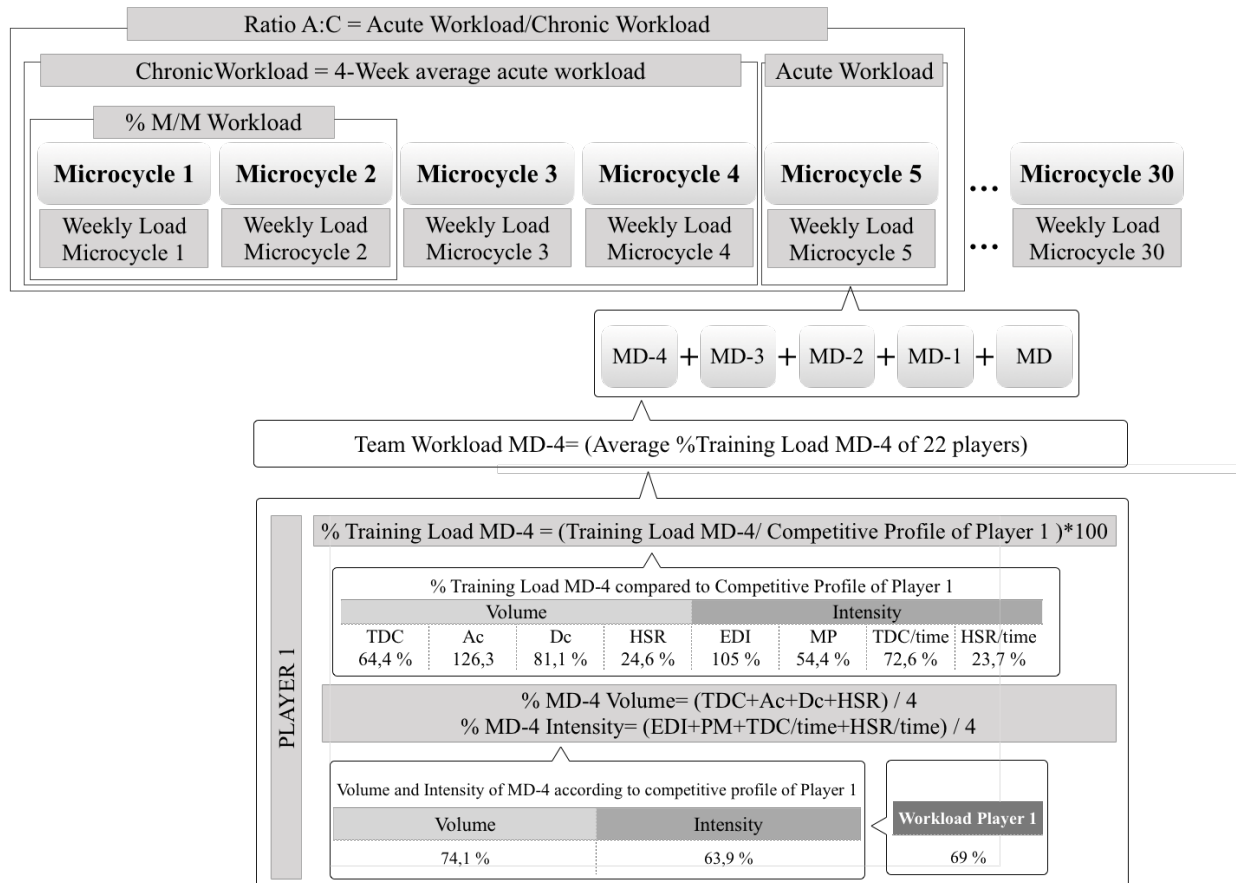
Figure 1: Multifactorial planning model for the monitoring and periodization of the training load in relation to CDP through GPS data

%M/M: Relationship between the load of a microcycle and the previous microcycle. MD: Match day. MD-*: Training session-* days to competitive match. CDP: Competitive dynamic profile. TDC: Total distance covered. AC: Number of acceleration. DC: Number of deceleration. HSR: High-speed running. EDI: Equivalent distance index. MP: Metabolic power. TDC: Relative distance covered. HSR/time: Relative high-speed running

2.3. Statistical analysis

This statistical analysis was carried out using SPSS software (version 22). A descriptive analysis of the study variables was made. Subsequently, the Kolgomorov-Smirnov test was used to check normality and homogeneity. The results showed non-parametric variables. The Kruskal-Wallis test was used to identify differences between the variables and subvariables of training intensity and volume. Significant interaction was further investigated using the Mann-Whitney *U* test.

3. RESULTS

3.1. Monitoring of the weekly load

Table 2 shows the percentage relationship between different variables of volume and intensity and the competition (MD). In this case, the MD value is determined by the average of the registered assessments during the 30 competitive matches in relation to the CDP. The maximum values reached in a competition match (MDmax) were also related to the MD (Table 2).

Table 2: Percent markers of volume and intensity in relation to the average value of the competition (MD)

	Volume				Intensity			
	TDC	Ac	Dc	HSR	EDI	MP	TDC/time	HSR/time
MD-4	55.1%	79.5%	72.6%	35.1%	97.6%	74.9%	77.1%	54.6%
MD-3	62.8%	59.2%	56.9%	63.2%	90.7%	101.3%	92.1%	93.2%
MD-2	32.8%	32.7%	30.6%	19.9%	76.5%	66.7%	67.5%	38.1%
MD-1	39%	41.7%	38.1%	38.3%	88.4%	69.6%	72.2%	69.0%
MD	100%	100%	100%	100%	100%	100%	100%	100%
MD_{max}	104.5%	136%	123.6%	127.2%	121.6%	109%	102.7%	124.9%
WL	289.7%	313%	298.2%	256.5%	453.1%	412.6%	408.4%	358.4%

TDC: Total distance covered. Ac: Number of acceleration. Dc: Number of deceleration. HSR: High-speed running. EDI: Equivalent distance index. MP: Metabolic power. TDC: Relative distance covered. HSR/time: Relative high-speed running. MD: Match day. MD-*: Training session-* days to competitive match. MD_{max}: Percentage ratio between the maximum value reached in a competition match and MD. WL: Percent of cumulative weekly load

The management of training load throughout the microcycle shows that MD-4 and MD-3 were more demanding than the rest of the sessions. The significance level between MD-4 and MD-3 relating the rest of the sessions was $p= .000$ and the relation between MD-1 and MD-4 obtained a significance of $p= .033$. Intensity was significantly higher than volume in all training sessions ($p= .000$).

MD was significantly more demanding than training sessions; significant differences with MD-3 in relation to intensity ($p= .961$) were not found. Volume of MD-4 and MD-3 was significantly higher than MD-2 y MD-1 ($p= .000$), not finding difference between them. Regarding intensity, there are significant differences between all training sessions except between MD-4 and MD-1 ($p= 1.000$) (see Figure 2).
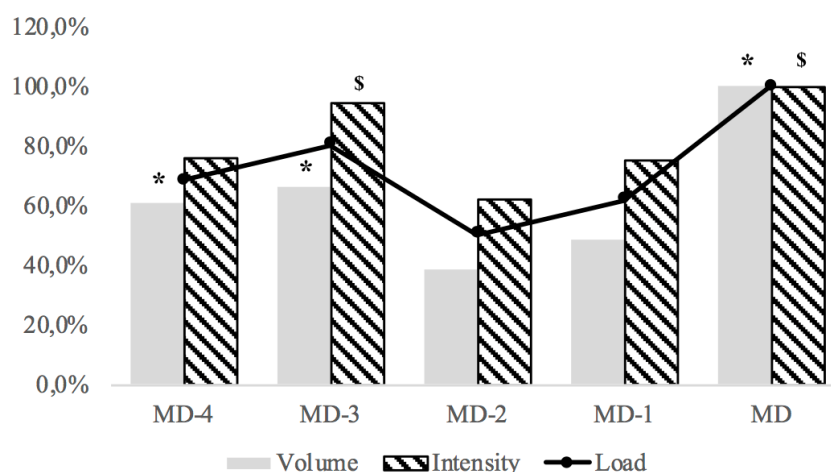

Figure 2: Representation of the average values in % of volume and intensity in relation to MD MD: Match day. MD-*: Training session-* days to competitive match. *Significant differences with MD-2 and MD-1 in relation to volume for $p< .001$. $Significant differences with MD-3, MD-2 and MD-1 in relation to the competitive profile for $p< .01$

Taking into account the different volume and intensity indicators, in MD-4 we can observe higher Ac, Dc and EDI than in MD-2 ($p= .000$) and MD-1 ($p= .001$).

HSR, MP, TDC/time and HSR/time were significantly higher in MD-3. Significant differences between MD-3 and MD in TDC/time and HSR/time were not found. MD-2 was the less demanding session since HSR was significantly lower in MD-2 than in MD-1 (p= .025) and MD-3 (p= .000), and EDI was significantly lower than in MD-3, MD-4 (p= .000) and MD-1 (p= .003).

3.2. Training periodization

The accumulated load (WL) showed an average of 313.74% more than MD, finding significant differences (p= .000) in all intensity variables (see Table 2). With respect to the analyzed variables, the cumulative weekly load of the number of accelerations (WLAc) and the cumulative weekly load of the number of decelerations (WLDc) were greater than the rest of the volume variables, and the cumulative weekly load of the equivalent distance index (WLEDI) was greater than the other intensity variables.

The periodization of the weekly training was analyzed through the relationship between the WL of a microcycle and the WL of the previous one (%M/M). According to the results obtained, the %M/M showed an average difference in load of 0.6%. Microcycle 14 showed the highest %M/M (15.4% more load than microcycle 13), while microcycle 23, was where less %M/M was shown (11.7% less load than microcycle 22) (see Figure 3).
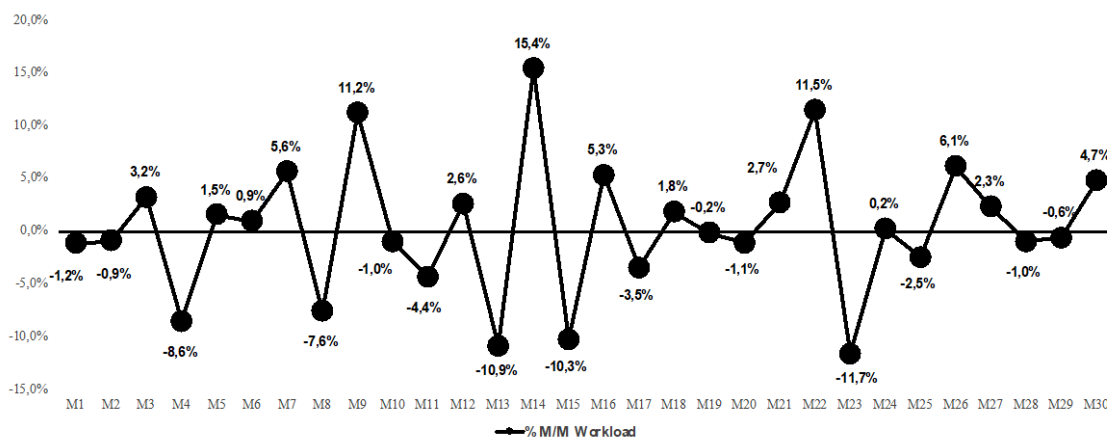

Figure 3: Representation of the M/M during the 30 competitive microcycles expressed in % M*: Microcycle

The periodization of the training in relation to the A: C ratio showed an average index of 1.00, observing variable values within a range between 0.89 and 1.13. Figure 4 represents the dynamic management of the A: C ratio in each microcycle. Microcycle 22 registered the highest index in the A: C ratio, while it was microcycle 13 where the lowest A: C ratio was observed (see Figure 4).
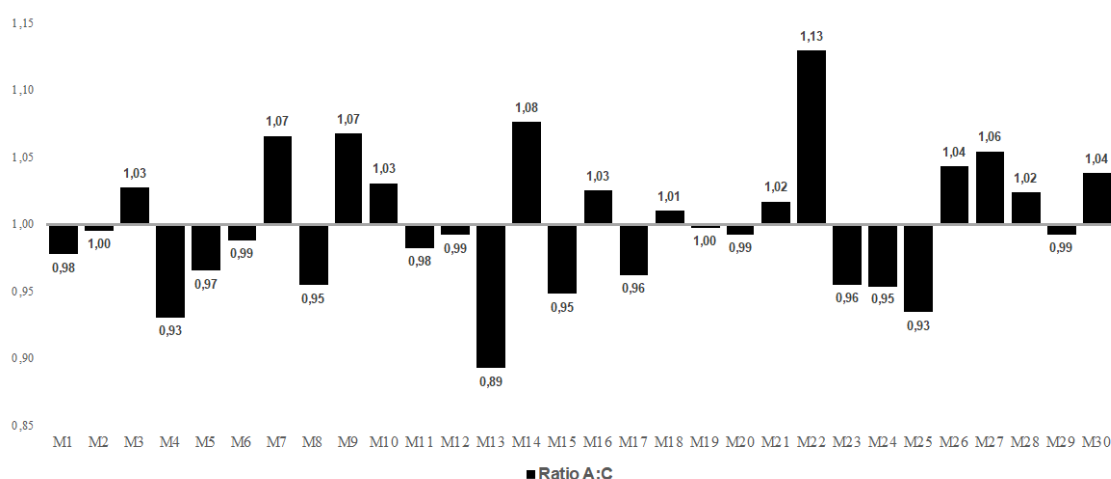
Figure 4: Representation of the A:C ratio during the 30 competitive microcycles
M: Microcycle

4. DISCUSSION

The aim of the present study was to describe a multivariate planning model for weekly monitoring of training and its periodization in relation to the CDP of the players of a professional soccer team in the Spanish league, using different variables registered with GPS. The variables used in this study to quantify the training load were chosen due to the impact they have on reliability and validity to determine the external load in team sports in a precise way[13,17].

The methodology to register the variables through a GPS device aimed at determining the team's training load using the average data of the analyzed players, as previously developed in other studies[2,5]. Such methodology turns out to be potentially favourable to monitor the load indicator in professional soccer players in relation to individual performance in competition[5].

According to current literature, studies that analyzed the control of training through the monitoring of the load in relation to the competition data were mainly based on the average competitive profile, taking as a reference the average of the data registered in the competition matches[16], and in the maximum competitive profile, taking into account the maximum results recorded in competition[5]. However, taking into consideration current research trends where it has been shown that success in soccer is multifactorial and complex[18] and that training and match demands can vary dramatically due to numerous contextual factors[15,19,20], it was considered that the average competitive profile and maximum competitive profile did not represent a real reference of the current performance of the athlete and the team. Thus, taking as a reference of fitness the trend of the last weeks[7,9], the originality of this multivariable model for monitoring the weekly load rests on the control of training, relating the load of the sessions with the CDP. However, considering that the maximum competitive profile can be identified as a worse scenario[21] and, therefore, as a situation susceptible to injury to be taken into account, this study also presented its values.

The dynamic load of the competitive microcycle turns out to be very similar to the one published recently[2,5]. When observing the results of the variables registered in this study, it can be assumed that the training load is very conditioned by the technical tactical demands of the competition model, since significant differences between volume and intensity were shown in each training session. These data do not match with the ones published by Owen et al.[5] in other studies. This can be due to the fact that, during the competitive phase of the season, coaches base the practice on the technical tactical development of players and on the maintenance of their physical capacities[2,13] through specific training, which can maximize the corresponding adaptations[15,20,22] while minimising the cumulative effects of fatigue and reducing monotony and training stress (18). Morgans et al.[20] recently showed the efficacy of specific training in relation to competitive demands of elite soccer players, considering that the game itself is an important stimulus of neuromuscular load to generate adaptations during the week.

Results show a load phase distant from the competition (MD-4 and MD-3) and a tapering phase (MD-2 and MD-1) prior to MD, as proposed in the literature[2,5,7]. According to traditional planning models, the results shown in this study observe the load variability along the microcycle to facilitate physiological adaptations[2,5,9]. Unlike other proposals published regarding Premier League players where the weekly tapering phase was limited to session MD-1[2,9], in this study we can observe a significant tapering of MD-2 and MD-1, as published recently[5], accentuating in session MD-2. Reducing the training load at the end of the week through the Ac, Dc and HSR variables seems to be an appropriate strategy to guarantee muscle functionality[25-27], since that neuromuscular demand could affect the susceptibility to suffer an injury[28] when facing the demands of competition with little time to recover. Unlike Malone et al.[9], the variables of neuromuscular load (Ac, Dc, HSR and HSR/time) in this study were higher in MD-1 than in MD-2. The findings recently published by Tsoukos et al.[27] suggest that a power training session with a low volume turned out to have an explosive muscular delayed performance after 24 hours, being advisable to carry out this type of training the day prior to competition.

Unlike Owen et al.[5], the findings of this research showed that MD-4 session has a higher neuromuscular demand than the rest of sessions, there being a greater amount of Ac and Dc, and a EDI of 97.6% in relation to the competitive profile. However, the variables related to metabolic load (TDC, HSR, TDC/time and HSR/time) were significantly higher in MD-3 session, as it already happened with some of these variables in other studies[5]. The results of the investigation showed that MP in the MD-3 session exceeded the values recorded in competition. Considering that this variable is very useful to estimate training load[2,17], it is assumed that MD-3 was a session with a metabolic demand very similar to competition demands. MD-4 and MD-3 were sessions with high volume and intensity indicators, and these findings are related to significant changes in physical ability of athletes[14]. In accordance with current methodological proposals[30], one might think that the distribution of the neuromuscular and metabolic demands represented in this study fit these proposals.

The findings of this study showed that weekly training planning guaranteed the stimulation of athletes at competition level, distributing the type of stimulus in two different sessions far apart from competition. These results coincided with those found in other publications[5,12,14,] where training should guarantee sufficient stimulus to condition the athlete's fitness, without exceeding the limits of physiological tolerance of players[2], generating a protective effect[9] through training without exposing the athlete's structures to overactivation by repetition of the same efforts on consecutive days.

As shown in other investigations, the accumulated load during the week exceeded competitive demands[2,5,13,16], showing that the accumulation of Ac, Dc, EDI and MP was significantly higher. Considering that abrupt changes in training load over a short period of time during the competitive period are related to the risk of injury[3,11], studies suggest avoiding aggressive changes in the load from week to week[3,11,31,32]. Accordingly, and despite the fact that in the current literature there is no clear reference related to the periodization of the short-term multivariate load in professional football, this study describes the distribution of the %M/M variable with the objective of showing the variability of the WL throughout the 30 weeks.

The results of this study revealed that the training periodization through %M/M remained within the safety interval suggested by literature to distribute the load in other team sports[4], whose main objective is to guarantee adaptation processes. and reduce the incidence of injuries[6,9,11,13]. According to Gabbett[6], both extremely high and low intensity training could generate a context susceptible to injury when facing the unexpected demands of competition. Therefore, avoiding great variations of the load in a short period of time could be closely related to injury prevention[6,9]. These studies suggest that %M/M remained constant, given that an increase of ≥15% M/M could increase injury risk between 21% and 49%[7]. The results of this study showed that %M/M ranged within the values established by previous studies (0.6%). Nevertheless, it is suggested to relate the load data registered in this study with injury epidemiology to know the truthfulness of this criterion as a predictor of injury risk.

The latest trends in training planning have been correlated with the management of acute and chronic load as an indicator of fatigue and athletes' ability to withstand such fatigue[5,7,8,12,31,32]. Recent reseach has suggested that A:C ratio has strong correlations with injury incidence[6,9,11,29-32]. The A: C ratio shows a dynamic representation of the athlete's preparation[9] to withstand the fatigue levels caused by training[32]. The results described in this study showed that the dynamic management of the load presented an A:C ratio that ranged between 0.89-1.13, respecting the sweet spot proposed by Gabbett[6]. According to literature[6], one might think that load management through the A: C ratio in values between 0.7 and 1.3 induces an optimal balance between the performance athlete status and the fatigue endured with which to reduce the risk of injury[6,32].

The findings of this study carried out with professional soccer players showed the monitoring of the weekly load through GPS technology, the management of

the microcycle accumulated load with respect to the previous microcycle, and the relationship between fatigue indicators according to athletes' fitness, as suggested by other authors in their studies[9]. According to the published results, it is considered that the multivariable model described in this study could serve as a reference to establish a favourable strategy with which to control individual and collective training in relation to the dynamic demands of competition.

5. CONCLUSIONS

The multivariate model for planning weekly training is considered an efficient method to monitor training load in relation to the performance profile of the footballer / team at that time. The competitive microcycles showed a loading phase with values close to those achieved in competition, but with differentiated stimuli on consecutive days , and a tapering phase prior to competition. The oscillation of the weekly accumulated load showed little variability between the microcycles, observing an average of 0.6%. The dynamic load management presented an A:C ratio that ranged between 0.89-1.13.

6. PRACTICAL APPLICATIONS

This study provides useful information regarding monitoring and periodization of training load in a professional soccer team. The multivariate training planning model allows to combine variables of mechanic, neuromuscular and metabolic load of sportspeople and relate them to the competitive dynamic profile of the player. It is suggested that through this model the opportunity arises to make an individual analysis of each player, a group analysis according to the position on the court or a collective analysis with the team, as presented in this work. This study shows reference values for coaches or physical trainers who work at this level, and it can be the starting point to prescribe training according to the weekly planning model.

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