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El Ratio Agudo:Crónico en jugadores profesionales en baloncesto - ¿es una herramienta útil para el control de la carga?

The Acute:Chronic Workload Ratio in professional basketball players – is it a useful tool to load control?

O rácio carga de trabalho aguda:crónica em jugadores profissionais de basquetebol – é uma ferramenta útil para o controlo da carga?

López-Sierra, Pablo[1], García-Rubio, Javier[1], Arenas-Pareja, María de los Ángeles[1], Ibáñez, Sergio J.[1]

[1]*Grupo de Optimización del Entrenamiento y el Rendimiento Deportivo (GOERD), Facultad de Ciencias del Deporte, Universidad de Extremadura, 10003 Cáceres, España.*

RESUMEN

El incremento de competiciones en baloncesto profesional ha generado un creciente interés en el control de la carga de los jugadores. El Ratio Agudo: Crónico es una herramienta muy común para controlar la variación de la carga en equipos profesionales. Sin embargo, se dan situaciones específicas en las que el RA:C está limitado si no se dispone de un histórico de los valores de carga. El objetivo de esta intervención fue analizar la carga de un equipo profesional a través del RA:C, incluyendo una revisión retrospectiva de su curva en aquellos escenarios en los que se desea obtener valores precisos de carga sin disponer de un histórico de las cargas de los jugadores. Un equipo profesional de diez jugadores participó en el estudio. Los dispositivos inerciales WIMU Pro fueron utilizados para cuantificar la carga de los jugadores durante el entrenamiento. Las variables de este estudio fueron la carga externa objetiva y subjetiva, la carga aguda y la carga crónica. Los resultados muestran la existencia de lesiones cuando la carga incrementa de manera desproporcional y figuran valores de riesgo de lesión en los jugadores. La incidencia lesional es del 20% cuando se superan los valores de riesgo. El estudio corrobora que el Ratio Agudo: Crónico es una herramienta práctica y útil para monitorizar la carga y su evolución durante el mesociclo sin realizar posteriores análisis estadísticos. Además, es útil para conocer las cargas de manera eminentemente práctica, encontrando asociaciones no causales con la apariencia de lesiones. Se recomienda una revisión retrospectiva de la curva cuando se desea conocer los valores de riesgo lesional y no se dispone de datos de una preintervención.

Palabras clave: deportes de equipo, dispositivos inerciales, cuantificación de la carga, carga externa, RA:C.

ABSTRACT

The increasing number of competitions in professional basketball has increased the interest in controlling player loads. The Acute:Chronic Workload Ratio is a very common tool for controlling load variation in professional teams. However, there are specific situations in which the ACWR is limited if no historical load values are

Correspondencia: **Pablo, López-Sierra.** Dirección Postal: Facultad de Ciencias del Deporte, Av. de la Universidad S/N, Cáceres, España. Tel: 927257827. Email: pablols@unex.es

Sociedad Iberoamericana de Psicología del Deporte

available. The objective of this intervention was to analyze the workload of a professional basketball team through the ACWR, including a retrospective review of its curve for those scenarios in which it is desired to obtain accurate values of injury risk without players' previous load values. A ten-player professional men's team participated in this study. WIMU Pro brand inertial devices were used to quantify player load during training. The variables in this study were objective and subjective external load, acute load and chronic load. The results show the existence of injuries when the load is disproportionately increased and enters very high risk values. The incidence of injury is 20% when the risk values are exceeded. The study corroborates that the Acute:Chronic Workload Ratio is a practical and useful tool to monitor the load and its evolution throughout the mesocycle without further statistical analysis. In addition, it is useful to know when to control the players' loads from an eminently practical point of view, finding non-causal relationships with the appearance of injuries. A retrospective review of the values is recommended if it is desired to refine the injury risk value in those measurements where pre-intervention load rates are not available.

Keywords: team sports, inertial devices, load quantification, external load, ACWR.

RESUMO

O crescente número de competições no basquetebol profissional tem aumentado o interesse no controlo das cargas dos jogadores. O rácio de carga de trabalho aguda:crónica é uma ferramenta muito comum para controlar a variação de carga nas equipas profissionais. No entanto, existem situações específicas em que o ACWR é limitado se não existirem valores históricos de carga disponíveis. O objetivo desta intervenção foi analisar a carga de trabalho de uma equipa profissional de basquetebol através do ACWR, incluindo uma revisão retrospetiva da sua curva para aqueles cenários em que se pretende obter valores precisos de risco de lesão sem os valores de carga anteriores dos jogadores. Participou neste estudo uma equipa profissional masculina de dez jogadores. Foram utilizados dispositivos inerciais da marca WIMU Pro para quantificar a carga dos jogadores durante o treino. As variáveis deste estudo foram a carga externa objetiva e subjectiva, a carga aguda e a carga crónica. Os resultados mostram a existência de lesões quando a carga é aumentada de forma desproporcionada e entra em valores de risco muito elevados. A incidência de lesões é de 20% quando os valores de risco são ultrapassados. O estudo corrobora que o rácio carga de trabalho aguda:crónica é uma ferramenta prática e útil para monitorizar a carga e a sua evolução ao longo do mesociclo sem uma análise estatística mais aprofundada. Além disso, é útil para saber quando controlar as cargas dos jogadores de um ponto de vista eminentemente prático, encontrando relações não causais com o aparecimento de lesões. Recomenda-se uma revisão retrospetiva dos valores se se pretender aperfeiçoar o valor do risco de lesão nas medições em que não se dispõe de taxas de carga pré-intervenção.

Palavras chave: desportos colectivos, dispositivos inerciais, quantificação da carga, carga externa, ACWR.

INTRODUCTION

Workload management during training and competition has become increasingly important in both individual and team sports. Hulin et al. (2014) defines workload in sports as the amount of stress accumulated by an individual as a result of multiple training sessions and competitions over a period of time. External load is considered to be the mechanical and locomotor stress produced by an activity that can be measured through kinematic and neuromuscular variables (Zurtuuza & Castellano, 2020). This also can be calculated with objective and subjective instruments (Gómez Carmona et al., 2019; Sánchez et al., 2014). Regarding the objective external load, kinematic variables that respond to the displacements of the athletes and the intensity of their movements can be recorded using Inertial Measurement Unit Systems (IMUS). The neuromuscular variables are the forces acting on the athlete, resulting from the interaction with gravity and team-mates/opponents, recorded by triaxial accelerometers (Boyd et al., 2011).

Is ACWR useful to load control?

In sports such as basketball, load monitoring is highly important, since it allows monitoring the risk of injury and the physical fitness of the players (Ibáñez et al., 2022; Mancha-Triguero et al., 2019); being important to know the physical demands involved in the development of training tasks and complete training (Bordón et al., 2021). When analyzing the load, a distinction is made between external load and internal load. The internal load can be monitored with objective parameters, using Heart Rate (bpm) (Gutierrez-Vargas et al., 2021) or lactate (mmol) (Castagna et al., 2010). The subjective internal load is obtained from the Rate of Perceived Exertion (au) (Borg & Dahlstrom, 1962). Furthermore, the quantification of external load in this sport has been performed in various ways: by time motion analysis (Barris & Button, 2008), by using inertial devices (Gómez-Carmona et al., 2019; Pino-Ortega et al., 2022), or using subjective load control systems such as SIATE (weighted load) (Ibáñez et al., 2016). In recent years, inertial devices are being increasingly used by clubs (Reina et al., 2022) because of their non-invasive nature (Fox et al., 2022). In the end, it is the coach who must manipulate the external load variables to prevent injuries due to fatigue (O'Grady et al., 2020), but always as well advised as possible. One of the tools used to control this weekly oscillation of the load is the Acute:Chronic Workload Ratio.

The Acute:Chronic Workload Ratio (ACWR) corresponds to the acute load and the chronic load accumulated by training for a minimum period of 21 days (Dalen-Lorentsen et al., 2021). Experts indicate that a difference greater than 1,5 between the acute and chronic load means an increased risk of injury (Dalen-Lorentsen et al., 2021; Soligard et al., 2016; Wang et al., 2020). Associated with this concept is the Sweet Spot. The Sweet Spot is the optimal stimulus range of training load that maximizes performance while limiting the negative consequences of training (e.g., injury, illness, fatigue, and overtraining) through the ACWR (Gabbett, 2016). This range is between 0,8 to 1,3 values of the ACWR. When the load is outside this threshold (values above 1,5), the risk of injury increases.

Two models are defined in the literature to calculate the ACWR, the coupled and the uncoupled (Nobari et al., 2022). The coupled model, the most commonly used, applies the same formula for the calculation of the acute and chronic load, taking into account the load of the day on which it is calculated and the previous day. The difference between the acute and chronic load is a constant that gives greater or lesser weight to the load of the previous day (in the chronic load the weight of the previous day is much greater). As a cumulative formula, the previous day's load is influenced by the load of all previous workouts for as long as load data are available. However, the uncoupled model does not take into account the historically accumulated loads, but is a more stable model in which only the acute and chronic load days that are considered to be of interest are taken into account. For example, if the most common uncoupled model, 7:28, is chosen, the average of the last 7 days would be made and divided by the average load of the last 28 days (Pajuelo & Caparrós, 2021).

Carey et al. (2017) proposes to use the 3:21 Ratio (taking into account 3 days of accumulated acute load and 21 days of chronic load), while most inertial devices calculate it from models such as 7:21 or 7:28. Following the models most commonly used in the literature, at least 21 days of monitoring is required to obtain reliable values, something that was detected by Blanch and Gabbett (2016), where players returning from injury after several weeks of injury gave outliers in the Acute:Chronic Workload Ratio due to the first fifteen days of accumulation of load after the return to play. This is of great importance in the scientific field, as it is not always possible to perform interventions with enough time to have chronic load data before the measurement. Professional clubs, however, do have the ability to collect data throughout the entire season, having complete monitoring of their players. In such cases, both ACWR models are considered effective in detecting injury risk in athletes (Dalen-Lorentsen et al., 2021; Soligard et al., 2016).

In the last 5 years, numerous studies have been published that question the methodological and statistical validity of the Acute:Chronic Workload Ratio (Impellizzeri et al., 2021). These doubts have arisen from the detection of the statistical noise that is generated when using the ratio to calculate the load or when performing statistical analyses with this variable (Impellizzeri et al., 2020). This is because ACWR is a rescaling of the explanatory variable, in turn magnifying its effect estimates and decreasing its variance (Impellizzeri et al., 2021). However, on a practical level, for a coach who does not have resources or who has devices with which to control the load, the ACWR can be a complementary tool that allows us to know how the load evolves by comparing the microcycle with the mesocycle and avoid drastic decompensations of the load that lead to a decrease in physical fitness or an excess load that results in overload; as long as these data are not used for future statistical analyses. When monitoring is performed at specific periods during the season, without historical load values, outliers can appear. These values produce a very unbalanced ACWR curve and do not allow an accurate prediction of the athlete's risk of injury. It is considered necessary to reduce the extreme values obtained in an objective way to control the load of the players. Formula smoothing to avoid the influence of outliers is quite common in various fields, including sports science when dealing with data that are sensitive to signal perception errors, as in the case of obtaining GPS-derived speed data with inertial devices (Cummins et al., 2023). Due to the discrepancies in the literature regarding the ACWR and the absence of solutions for its use in players returning to training due to injury or in scientific cross-sectional measurements, the main objective of the present research is to analyse the ACWR from an eminently practical point of view, without statistical analyses that generate statistical controversies, proposing a solution to reduce outliers in special situations.

MATERIAL AND METHODS

Experimental design

According to the logic of the research plan, this study was categorized as empirical with quantitative methodology, ex post facto, evolutive, and longitudinal, since through the use of inertial devices, comparisons were established in the chronic workload, analyzing how this variable evolved over 4 weeks within the same group of subjects. Furthermore, this study was carried out using an arbitrary code of natural observation, taking place in the usual context in which the phenomenon occurs, without the intervention of the researcher in what he/she observes (Montero & Leon, 2007). According to the classification of research designs in psychology, a descriptive observational methodology with a multidimensional ideographic point design was used (Ato et al., 2013).

Participants

A team of ten men players competing in the Liga LEB Oro (Spanish Second Division) during the 2021/2022 season (age=26,7±3,129 years; height=194,8±7,843 cm) were the participants in this study. Participants were chosen using non-probability convenience sampling (Hernández et al., 2006), due to the difficulty of obtaining data in this type of population. Players, coaches and team managers were informed prior to the research about the potential risks and benefits of participation. Participants decided to participate on a voluntary basis, and an informed consent form was signed by the team's coaches, managers, and basketball players. The research was conducted following the criteria of the Declaration of Helsinki (2013), the Ethical Standards in Sport and Exercise Science Research of Harriss et al. (2022) and was approved by the University Bioethics Committee (233/2019). The investigation respected the framework of Organic Law 3/2018 of 5 December on Personal Data Protection and guarantee of digital rights.

Eligibility Criteria.

To participate in this study, the following inclusion and exclusion criteria were defined. Inclusion criteria: (i) having trained with the team all season, (ii) not being injured due to overload in the previous 2 months before the intervention, (iii) not training with other teams than the one being monitored.

Exclusion criteria were: (i) not attending 80% of the training sessions, (ii) not playing 2 or more matches during the measurement period, and (iii) having an injury not related to overload.

The data sample was obtained from monitoring during 3 weeks, with a total of 14 training sessions, developed during a mesocycle of the second competitive phase of the regular league. Final load values were recorded from each training session for each player (ten data per training session), and one general data point for the team per training session, using the Player Load variable. The total load data represented 154 records.

Instruments

The workload of each player was measured with WIMU Pro IMUs (Real-Track Systems, Almeria, Spain). Along with these instruments, GARMIN heart rate monitors (Garmin Ltd, Kansas, USA) were used. To measure the positioning of the basketball players, an ultra-wideband (UWB) radiofrequency system was used to quantify the loads in indoor spaces.

Procedure

The team's physical trainers were contacted to discuss the purpose of the research and the different data to be collected. The schedules of the different training sessions to be carried out each week were also agreed upon, as well as the planning of the matches.

The variables in this study were: (i) objective external load, using the Player Load value and the ACWR; (ii) acute load and (iii) chronic load (Table 1).

Tabla 1

Variables in the study.

Variable	Variable dimensions
Objective External Load	Player Load, ACWR
Acute Load	Acute Player Load (accumulated or 7 previous days)
Chronic Load	Chronic Player Load (accumulated or 28 days)

Data collection was carried out in all the training sessions. First, the UWB system was set up throughout the field. Then, the athletes were equipped with inertial devices for data collection. At the end of the training session, the data were extracted to a computer for analysis with the SPro tool. After extraction, they were uploaded to the cloud storage where they were subsequently processed (RealTrack Systems, Almeria, Spain).

The ACWR plots were created with the data stored in the cloud. Using the original data, retrospective smoothing of the values was performed, since the load records prior to monitoring were not available. This smoothing was carried out in the 2 dimensions of the calculation of acute and chronic loads, coupled and uncoupled.

Coupled model.

The formula proposed by Nobari et al. (2022) was used to calculate the ACWR with the coupled model:

$EWMAtoday = Loadtoday * \lambda + ((1- \lambda) * EWMAyesterday)$,

Using the 7:21 formula, the value of ʎ was 0,09 for acute load and 0,07 for chronic load, as can be seen in the work of Nobari et al. (2022).

The coupled formula consisted of the sum of 2 different calculations. The first part used the day's load based on the Player Load. The second part used the final load value of the previous day. Both values were weighted as a percentage, with the 2 values adding up to 100%. The percentage weight was higher for the previous day's final load than for the day's training (the percentage of the previous day's load is 91% for the acute load and 93% for the chronic load).

If this calculation was made in the first training session of the season, it is true that there was no previous load value and, a priori, the training was not going to generate a very high load. The data from the first 15 days should simply be taken with caution to predict injuries, since there was no scientific evidence that the formula worked in such short periods. However, since this data collection took place in the middle of the season, the absence of load that was assumed was not real. Since the accumulated load of the previous days was so important in the weighting of the formula, the error was prolonged over a long period of time and the ACWR values spiked during the first 15 days. If it was started with a simulated load, using a hypothetical zero-day, the loss of the value that had greater importance in the formula was avoided. To generate the value of this zero-day, it was proposed to perform a smoothing in the coupled model. This smoothing was not instantaneous, since it cannot be applied until all the measurement load data is available. This occurs because it is considered that to simulate the zero-day, real load values should be used, based on the principle that the loads between 2 consecutive months should not be far apart, so the smoothing was performed with the average of all the factors involved in the formula (Player load, Acute Load and Chronic Load).

Uncoupled model.

In the uncoupled formula, averages of weekly load and total load were used to obtain acute load (weekly average) and chronic load (total average) values. Since no previous load values were available, during the first week the ACWR values could not be calculated. This absence of values also influenced the calculation of the second week's load, meaning that half of the load data available was not correctly calculated. To solve this problem, the average of all chronic loads from the measurement was calculated and applied to the first 2 weeks, trying to emulate the previous unquantified load using data obtained in the actual measurement. The other week of monitoring is not smoothed, since after 15 days the cumulative load data are considered reliable.

Análisis estadístico

Once the data were obtained, they were processed in the software of the inertial devices. Using this data, load variables were obtained to perform the different ACWR calculations. These raw data were integrated into the WIMU Cloud. In the cloud, the type of formula to be applied was chosen, obtaining tables with the different Player Load, Acute Load, Chronic Load and ACWR data. These tables were exported in .xls format to facilitate further study.

After analysis of the actual load data obtained from the coupled and uncoupled formulae, a proposal was made to smooth the formula due to the cross-sectional nature of the study. For this, the only intervention of the researchers was to generate previous load data for the coupled model, as the coupled averages require load values from previous training sessions and the club's physical trainers did not have objective player load data in the months prior to the monitoring. Without players' load data, the ACWR formula would start from chronic load values equal to “0”. However, the cross-sectional measurement was performed in the final phase of the season, where the actual chronic load values should be very high and the absence of pre-load data contrasted sharply with the acute load applied in training sessions at the time of the measurement. For the simulation of the previous training load, the available measurement data were used, generating an average load value from the acute load applied during the monitored time to generate the chronic load data. In this way, instead of starting from ‘0’ acute load and ‘0’ chronic load values, it started with a chronic load value closer to the accumulated load after the entire training season. In this way, if several days of acute load are available, without reaching the 21 days of chronic load necessary to implement the ACWR formula, real chronic load values can be simulated based on objective data from the monitored team itself, thus being able to use the formula in players who join the group after injury and in cross-sectional interventions.

RESULTADOS

Table 2 shows the ACWR results obtained with the coupled formula without smoothing. Values above the injury risk (ACWR ≥ 1,5) are marked in bold. The results of the ACWR with the correction proposed in this work from the average of the Player load, Acute load and Chronic load are also presented.

Table 2

Coupled ACWR values.

		Unsmoothed ACWR					Smoothed ACWR		
Session	**PL (a.u.)**	**Acute**	**Chronic**	**ACWR**	**Date**	**PL (a.u.)**	**Acute**	**Chronic**	**ACWR**
					Day 0	36.69	30.93	21.12	
Training	28.78	7.20	2.62	**2.75**	Day 1	28.78	30.39	21.66	1.40
Training	39.54	15.28	5.97	**2.56**	Day 2	39.54	32.68	22.91	1.43
Training	68.72	28.64	11.68	**2.45**	Day 3	68.72	41.69	26.11	**1.60**
Match	0.00	21.48	10.62	**2.02**	Day 4	0.00	31.27	24.29	1.29
Rest	0.00	16.11	9.65	**1.67**	Day 5	0.00	23.45	22.59	1.04
Training	45.47	23.45	12.91	**1.82**	Day 6	45.47	28.95	24.19	1.20
Training	80.96	37.83	19.09	**1.98**	Day 7	80.96	41.96	28.16	1.49
Rest	0.00	28.37	17.36	**1.63**	Day 8	0.00	31.47	26.19	1.20
Match	0.00	21.28	15.78	1.35	Day 9	0.00	23.60	24.36	0.97
Rest	0.00	15.96	14.35	1.11	Day 10	0.00	17.70	22.65	0.78
Training	47.29	23.79	17.34	1.37	Day 11	47.29	25.10	24.38	1.03
Training	69.89	35.32	22.12	**1.60**	Day 12	69.89	36.30	27.56	1.32
Match	0.00	26.49	20.11	1.32	Day 13	0.00	27.22	25.63	1.06
Rest	0.00	19.87	18.28	1.09	Day 14	0.00	20.42	23.84	0.86
Training	70.26	32.46	23.00	1.41	Day 15	70.26	32.88	27.09	1.21
Training	89.67	46.77	29.06	**1.61**	Day 16	89.67	47.08	31.47	**1.50**
Training	63.74	51.01	32.22	**1.58**	Day 17	63.74	51.24	33.73	**1.52**
Training	66.26	54.82	35.31	**1.55**	Day 18	66.26	54.99	36.01	**1.53**
Training	41.46	51.48	35.87	1.44	Day 19	41.46	51.61	36.39	1.42
Match	0.00	38.61	32.61	1.18	Day 20	0.00	38.71	33.84	1.14
Rest	0.00	28.96	29.64	0.98	Day 21	0.00	29.03	31.47	0.92
Training	81.54	42.10	34.36	1.23	Day 22	81.54	42.16	34.98	1.21
Training	50.25	44.14	35.81	1.23	Day 23	50.25	44.18	36.05	1.23

PL=Player load; ACWR=Acute:Chronic Workload Ratio. Load values exceeding the injury risk zone (>1.5) are highlighted.

As can be seen in Table 2, in the unsmoothed ACWR the players exceeded the risk value for 12 days, while in the smoothed ACWR they only exceeded that value on 4 occasions. These extreme values are accumulated mainly in 2 weeks, the first and the third. After seeing the amount of data exceeding the risk value, it was decided to extract the data with the uncoupled formula.

Table 3 shows the uncoupled ACWR data with the original data and the smoothed data, highlighting the values at risk of injury.

Table 3
Uncoupled ACWR values.

	Unsmoothed ACWR					Smoothed ACWR			
	PL (a.u.)	**Acute**	**Chronic**	**ACWR**	**Date**	**PL (a.u.)**	**Acute**	**Chronic**	**ACWR**
Training	28.78	7.20	2.62		Day 1	28.78	7.20	21.12	0.34
Training	39.54	15.28	5.97		Day 2	39.54	15.28	21.12	0.72
Training	68.72	28.64	11.68		Day 3	68.72	28.64	21.12	1.36
Match	0.00	21.48	10.62		Day 4	0.00	21.48	21.12	1.02
Rest	0.00	16.11	9.65		Day 5	0.00	16.11	21.12	0.76
Training	45.47	23.45	12.91		Day 6	45.47	23.45	21.12	1.11
Training	80.96	37.83	19.09	**14.46**	Day 7	80.96	37.83	21.12	**1.79**
Rest	0.00	28.37	17.36	**10.84**	Day 8	0.00	28.37	21.12	1.34
Match	0.00	21.28	15.78	**3.56**	Day 9	0.00	21.28	21.12	1.01
Rest	0.00	15.96	14.35	1.37	Day 10	0.00	15.96	21.12	0.76
Training	47.29	23.79	17.34	**2.47**	Day 11	47.29	23.79	21.12	1.13
Training	69.89	35.32	22.12	**2.74**	Day 12	69.89	35.32	21.12	**1.67**
Match	0.00	26.49	20.11	**2.05**	Day 13	0.00	26.49	21.12	1.25
Rest	0.00	19.87	18.28	1.04	Day 14	0.00	19.87	21.12	0.94
Training	70.26	32.46	23.00	**2.06**	Day 15	70.26	32.46	23.00	1.41
Training	89.67	46.77	29.06	**3.26**	Day 16	89.67	46.77	29.06	**1.61**
Training	63.74	51.01	32.22	**2.94**	Day 17	63.74	51.01	32.22	**1.58**
Training	66.26	54.82	35.31	**2.48**	Day 18	66.26	54.82	35.31	**1.55**
Training	41.46	51.48	35.87	**2.56**	Day 19	41.46	51.48	35.87	1.44
Match	0.00	38.61	32.61	**1.92**	Day 20	0.00	38.61	32.61	1.18
Rest	0.00	28.96	29.64	**1.58**	Day 21	0.00	28.96	29.64	0.98
Training	81.54	42.10	34.36	**1.83**	Day 22	81.54	42.10	34.36	1.23
Training	50.25	44.14	35.81	**1.52**	Day 23	50.25	44.14	35.81	1.23

PL=Player load. ACWR=Acute:Chronic Workload Ratio. Load values exceeding the injury risk zone (>1.5) are highlighted.

In the unsmoothed uncoupled model, 15 of the 17 values are above the risk of injury. The 2 days outside this injury risk are found after at least 2 days without load. The smoothed uncoupled model only includes 5 days at risk, of which 3 are consecutive in the third week (the week with more training sessions).

Upon detecting that the values were also very high in the uncoupled model, both formulas were analyzed in search of why these values were at risk. When reviewing the formulas, it was detected that they were influenced by the absence of load data prior to the measurement. As the previous load data were not available, we proceeded to propose an alternative based on retrospective smoothing of the data obtained during the measurement. Between days 16 and 18, all 3 formulas show injury risk, both with the smoothed and unsmoothed models.

Figures 1 and 2 present comparisons between the original and smoothed values of the coupled and uncoupled Acute:Chronic Workload Ratio respectively. A red line is included to determine the injury risk threshold.

Figure 1
Normalization of the coupled Acute:Chronic Workload Ratio during the time period analysed.

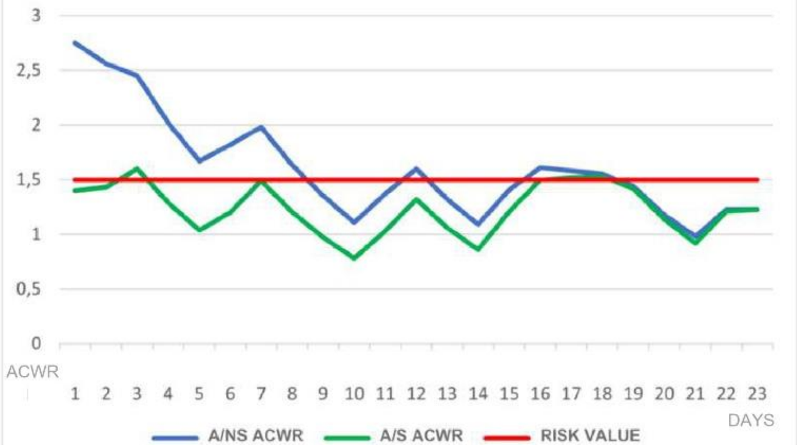
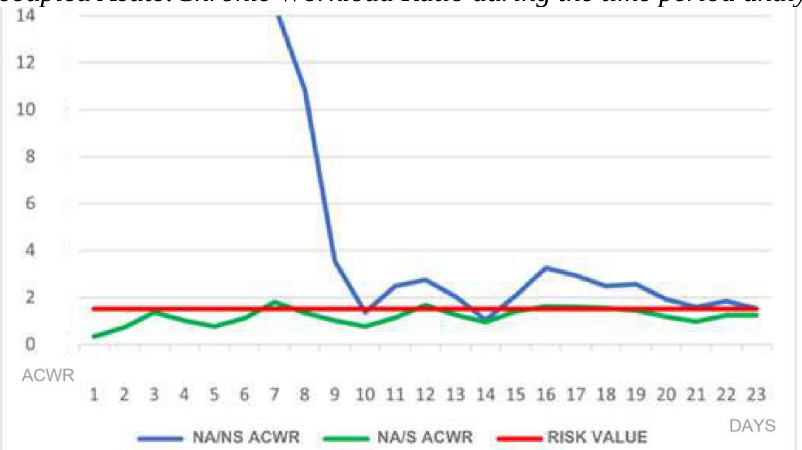


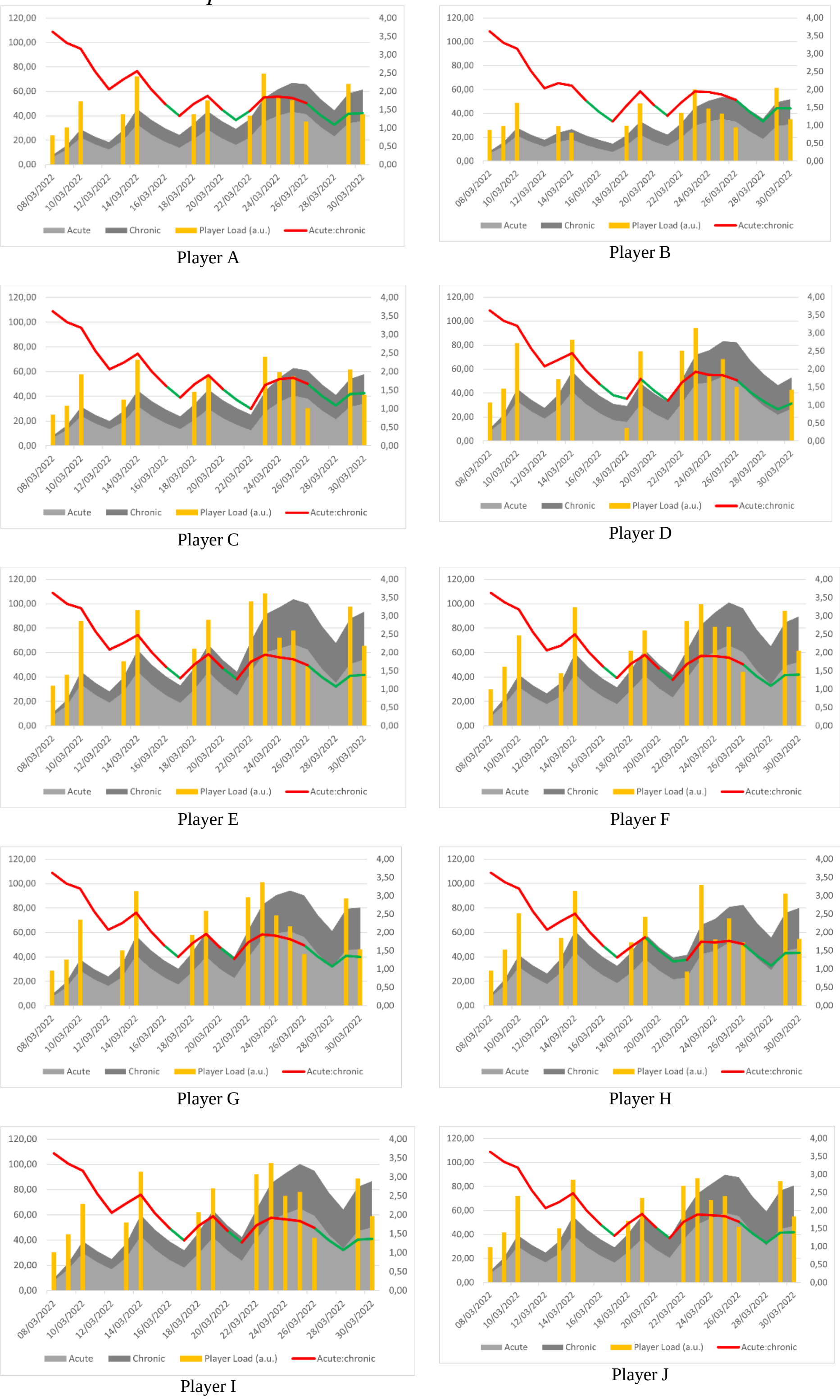
Figure 2
Normalization of the uncoupled Acute:Chronic Workload Ratio during the time period analyzed.



After applying the retrospective correction, since there is no historical record of the team's load, a decrease in the number of sessions with a high risk of injury is observed. These collective values are also presented individually per player. Figure 3 presents the unsmoothed coupled ACWR values per player. The choice of this formula is due to the fact that it is the least influenced by the extreme values without smoothing and because it is more complete as it uses the historical accumulation of all the load data previously available. It is worth highlighting the results of players H and I. As can be seen, the ACWR in both players during the third week was greater than 1,5. These players suffered a muscle injury in the days following the recording of the data.

Figure 3

Players unsmoothed coupled ACWR values.



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Note: The left Y-axis refers to the Player Load (a.u.) values, the right Y-axis represents the ACWR formula values and the X-axis represents the chronological training-competition dates.
This information allows an individualized analysis of the player's load. Although all players perform the same training processes, not all of them bear the same load during training.

DISCUSSION

The general objective of this study was to analyze the training load of a professional team during the season through the ACWR, as well as the inclusion of a retrospective smoothing of the load data for those situations in which previous chronic data are not available, identifying the moments of injury risk during the analyzed period. The application of the ACWR after a period of unquantified load results in the appearance of unrealistic injury risk values. These rates should be considered with caution, as a priori they may not pose a risk to the health of the athlete. Using real load data obtained during equipment monitoring to simulate the load quantification prior to the collection of the data, it is possible to reduce the appearance of unrealistic injury risk levels. This way, those data that exceed the value of 1,5 are more closely adjusted to reality in order to manage the health of the athlete, removing values that exceed the risk levels but that do not really pose a risk of injury (Fig. 1 and 2).

The original data obtained using the coupled model reveal twelve days of injury risk, which is half of the monitoring days. Of these twelve values, 8 were observed in the first days. The same occurs with the uncoupled model, since out of seventeen values obtained, fifteen appear in the risk zone. Coyne et al. (2019) detect that the formula is affected if the preseason data are not collected, and data are collected directly in the season. Impellizzeri et al. (2021) point out that statistically the ratios have a lot of noise, and that in the case of the ACWR the noise depends on previous injuries and the distribution of the data. In this study the noise is due to the distribution of the data, since the measurement was carried out in the second half of the regular league, and the players had been training for several months. However, quantitative values of previous load are not available, so these values obtained present outliers, which require retrospective smoothing. Nevertheless, the information obtained is relevant for the coaching staff, which lacks objective data on its intervention.

Comparing the data originally obtained with each model, it can be seen that in the uncoupled model the values present greater risk than in the coupled model. Murray et al. (2017) and Arazi et al. (2020) in their studies recommend the use of the coupled model (also called EWMA) because it is more sensitive to load changes. This is because the formula makes use of all previous load data available, whereas the uncoupled model only considers the values of the previous seven days for acute load and a maximum of 28 days for chronic load. The recommendation of these authors coincides with the researchers' one, which is why the graphs of the players are shown taking as a reference the values of the coupled model without smoothing.

In the coupled model the values are elevated at 2 moments: the first week and 3 consecutive days of the third week. Authors such as Baki et al. (2022) also find higher values in the ACWR during the first 2 weeks, something that happens due to the nature of the formula, since the chronic load data are smaller. However, in the third week, 5 consecutive workouts are accumulated, which are the ones that give rise to risk values. This accumulation of workouts is unprecedented during the season and corresponds to one of the most decisive matches of the competition. Chena et al. (2021) do not recommend modulating the load between weeks in long duration competitions because they can produce an excess of fatigue and a decrease in performance in the weeks of high loads. This risk of injury presented by the entire team can trigger problems in the health of the players, as well as in the results after that week due to possible absences of important players.

During the week after that of high load accumulation (third week of the measurement), players H and I were injured (discomfort in the lumbar region and left hamstring overload, respectively). Both players reached values close to 2 in the ACWR. Hulin et al. (2014) finds that the onset of possible injuries predicted by the ACWR has a certain delay, usually relative to 1 week. Furthermore, the same author mentions that the higher the value of the ACWR reached, the greater the injury that can be triggered in the athlete. It was player I who reached the maximum value (1.93) and the one who suffered the most severe injury. Bowen et al. (2020) state that values exceeding the injury risk and approaching the numerical value "2" increase up to 6 times the injury risk, finding greater evidence in the occurrence of injury to the 2 players. Dalen-Lorentsen et al. (2021) find that 20% of players who exceed the risk value (1.5) end up getting injured. This percentage is fulfilled in our sample, as it was of a total of ten players. It is important, not only to control the loads, but also to apply rest to those players who exceed the risk value by a wide margin, because rapid increases in work volume or intensity, which are not accompanied by sufficient time to generate adaptations, can lead to a disruption of homeostasis resulting in overworkload injuries for which the player was not suited.

Monitoring training sessions is practical and useful to obtain information that allows coaches to know how the training process is developing, as well as to identify moments when the workload increases disproportionately, not allowing the player to generate physiological adaptations and increasing the likelihood of an overload injury occurring in short periods of time. The smoothing of the ACWR curve is useful for adjusting loads when a team cannot be continuously monitored throughout the beginning of the season.

The main limitation of this study is the lack of match data to quantify the total load of the athletes because the competition did not allow the use of these inertial devices. It is recommended in future research to add the subjective load to give greater quality to the data obtained (Calvert et al., 1976; Hulin et al., 2014; Soligard et al., 2016), including mental workload values. Furthermore, as it is not possible to monitor matches due to regulatory issues, researchers are advised to take into account the playing time of the players in each match and can also use game statistics and match location as additional information complementary to the load. With regard to the doubts that exist in the literature on the use of this type of formula to predict injuries, it does not have scientific validity and rigour when used for statistical analysis (Atkinson & Batterham, 2012), as the ratio will generate noise when using various statistical models. However, when the value of 1,5 is exceeded in the formula, on a practical level, there are numerous studies in the literature that relate risk to an increase in the probability of an injury appearing (Malone et al., 2017; McCall et al., 2018), without being able to establish a cause-effect relationship to date. Thus, although in the authors' opinion, from a practical point of view it is a useful and simple tool to control the load, it is recommended for future research to try to find a statistical cause-effect relationship, and for coaches and physical trainers to accompany the results of the formula with other metrics such as subjective questionnaires of the player's perception of the load.

CONCLUSIONS

The ACWR is a tool that allows workloads and their variation to be monitored when players are systematically monitored during training and competition. In particular, the use of the Player Load variable for the calculation of the load in basketball players allows to know correctly the evolution of the athlete. The smoothing of the ACWR curve is useful for adjusting loads when a cumulative history of the whole season is not available.

PRACTICAL APPLICATIONS

Coaches are advised to monitor the training load and its variation throughout the season to control drastic swings in load over short periods of time, without the necessary adaptations to tolerate a higher load having occurred. The ACWR is effective in controlling such variations in load, provided it is not used in predictive statistical analyses, where it could generate statistical noise. It is recommended to use variables that allow the training load to be assessed taking into account the intensity of the training, avoiding very general variables that are traditionally used, such as training time or distance, as they do not take into account the intensity of the training. The use of variables that measure the mental load is also recommended, as well as taking into account the possible load that is generated in the athletes as a result of travelling to away matches or the playing time in matches when the load resulting from these is not available.

Is ACWR useful to load control?

Sometimes, the total load data of the season is not available due to various reasons (injuries, training with national teams, measurements made by external personnel...). For these cases, when the data collection occurs during the training process, with the players having passed phases of accumulation of training load, the ACWR does not have values of the previous chronic load that the players have performed. In such situations it is recommended to simulate the chronic load with real acute load values available during the monitoring days, in order to objectively and retrospectively generate an assimilated load accumulation based on real data close to the load of the previous weeks, because the load oscillation between weeks should never be too high if the health of the players is to be preserved. It is recommended to average the acute load of the first training sessions until day 14, when the chronic load data can be used with validity. In this way we do not start from a chronic load value equal to '0' when players have trained in the weeks or months prior to obtaining the data.

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