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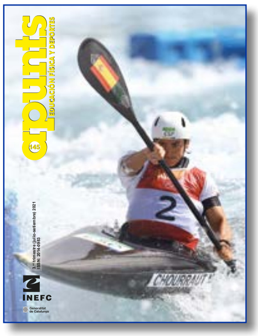

Acute:Chronic Workload Ratio. Exploration and Applicability in Women's Amateur Football

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Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract

With the objective of analysing the possible relationships between the acute:chronic workload ratio modalities (both by consecutive workload averages - ACWR, and exponentially weighted moving average - EWMA) and injury rate in women's football, a quasi-experimental non-intervention study was performed of the ratios obtained in the 212 training sessions and matches held in the course of one season in a women's amateur football team ($N = 17$). The variables used to calculate the acute load and chronic load ratios were the subjective ratings of perceived exertion (RPE) in relation to the internal load, each player's exposure time during the sessions as the external load (LOAD) and specificity (SP) in relation to the training schedule. The statistical analysis showed significant differences in the injury variable in the RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:28, 7:21), LOAD EWMA (4:16, 7:28, 7:21) and LOAD ACWR (4:16, 7:28) ($p < .005$) ratios, as well as significant associations in the injury rate in the ratios shown, except in SP EWMA 7 28 ($p = .47$). The results might suggest the applicability of ACWR and EWMA in controlling load in women's amateur football in relation to injury rate, with the use of EWMA providing higher sensitivity..

Keywords: ACWR, EWMA, injury prevention, load control.

Introduction

Football has undergone changes in its development which have led the game's pace and intensity to increase (Bowen et al., 2017), a factor which may have led to the application of workloads verging on the tolerance limit to boost the possibilities of success (Bowen et al., 2017). In high-performance football, epidemiological studies describe an injury rate of approximately 9 injuries for every 1000 hours of exposure and a mean of two injuries per player and season, which could lead to the loss of up to 37 days a season (Ekstrand et al., 2011).

Football is an intermittent sport which combines high-intensity actions with recovery or low-intensity periods, also involving stringent physical and emotional demands (Malone et al., 2017). In view of these needs, managing training and competition loads is a tool that can be used to prevent injuries (Carey et al., 2017) by avoiding inappropriate loads that could increase the injury rate (Gabbett, 2018), ultimately preventing players from participating fully in future practice sessions or matches (Ekstrand et al., 2011).

In this regard, the use of workload control as an injury prevention tool continues to be conditioned by the technical staff's level of experience or understanding (Fanchini et al., 2018), reducing its possible effectiveness and applicability in highly complex work groups and environments (Gabbett, 2018).

Hulin et al. (2014) proposed a relationship between acute load and chronic load, which related (acute) physical fitness to (chronic) fatigue. The relationship between these two types of load (known in the literature as ACWR, acute chronic workload ratio) sets out to analyse the effects caused by training by comparing the athlete's training load to the load for which they may be prepared (Gabbett, 2018) based on the average accumulated load in the previous weeks, making it possible to obtain a sample of the dynamic representation of the athlete's preparedness (Malone et al., 2017). This ratio would quantify the accumulated amount of stress produced in a person through different training sessions and matches during a given time period (Hulin et al., 2014).

Workload is defined by external load (EL) and internal load (IL), as well as by specificity (SP) (Zamora et al., 2021). The variables for quantifying EL are related to the amount of work the athlete does, while IL refers to the relative physiological and psychological tension imposed on the athlete, whereby different individual internal responses are given to the same EL (Zamora et al., 2020). This response is determined, among other variables, by the way the EL is applied, the athlete's characteristics and the SP (Casamichana et al., 2012). In this sense, variables such as the number of players, the number of exercises, the presence or absence of goalkeepers and/or the presence or absence of goals give rise to a greater or lower degree of cognitive stimulation and conditional demands, and consequently to different effects on training levels (Casamichana et al., 2012).

To calculate the ACWR, an EL and/or an IL variable is used, which must be specific and replicable (Hulin et al., 2014). The EL variables used may be specific and replicable, such as exposure time (Sampson et al., 2016), shots (Hulin et al., 2014), accelerations (Carey et al., 2017), etc. For IL, some proposals use heart rate variability (Williams et al., 2017), although the rate of perceived exertion (RPE) is a useful variable for reporting physiological and psychological stress in different group modalities (Carey et al., 2017; Malone et al., 2017; Fanchini et al., 2018) and is more applicable than heart rate in football, given its intermittent nature (Rodríguez-Marroyo & Antoñan, 2015). The RPE, understood as the subjective response to a stimulus, has a multifactorial (Borg, 1990) and multidimensional perspective, and presents low variability (Casamichana et al., 2012), which is often used in football (Impellizzeri et al, 2020). With regard to SP, to the authors' knowledge, this variable is not addressed in the literature in relation to ACWR, even although it defines the complexity of the sessions and their possible relationship with injury rate, as it influences both IL and EL (Casamichana et al., 2012).

By interpreting the ACWR, this value's relationship with a higher or lower likelihood of injury can be interpreted, as in contactless injuries, in both Australian football (Carey et al., 2017) and in young élite footballers (Bowen et al., 2017). In professional football (Malone et al., 2017), players were seen to be less likely to sustain injuries when they were exposed to moderate-low to moderate-high acute:chronic ratios between values of .8 and 1.5. These load ratios could be used to optimise the daily management of the training load (Malone et al., 2017) and to improve injury prevention (Murray et al., 2016). Other authors, such as Williams et al. (2017), state that the ACWR moving average method does not accurately represent the nature of adaptations to training and fatigue. For this reason, they suggest updating the ACWR using the exponentially weighted moving average (EWMA). This method might favour the emphasis and sensitivity of the workloads towards the end of the calculation cycle (Sampson et al., 2016), which could be more applicable to the nature of the training, rendering it possible to control the progression of the loads and only their possible effect (Foster et al., 2018). In their study with Australian football players, Murray et al. (2016) report how EWMA presents greater sensitivity to injuries than ACWR during the preseason and season.

However, there is an ongoing debate on the reliability of these load control methods and their possible relationship with the injury rate. For contactless injuries, it may not be a reliable predictive tool (Fanchini et al., 2018) due to a predictive sensitivity below 25 % in all cases. For open sport systems, the prediction of injuries could not be limited solely to monitoring a number (Buchheit, 2016), as this fails to address the context in all its complexity. From a statistical standpoint, there are two possible errors. First, there is a connection between acute load and chronic load, meaning that acute load could be a useful predictor in itself without the need to standardise it with regard to chronic load, since the two indicators used are related to each other (Lolli et al., 2018). This connection may yield false correlations, as also occurs due to the proportion of events recorded with regard to the injuries sustained (and recorded), leading to an exponential increase in the magnitude of the acute workload and of the possible ratios found (Impellizzeri et al., 2020).

In this context, the objective of this study is to explore the applicability of the ACWR and the EWMA in managing load control as an injury prevention tool in women's amateur football.

Methodology

Design

A quasi-experimental non-intervention study was conducted by means of retrospective observation and an ex-post facto design, since the training sessions and injuries sustained by the different players in the team were monitored with a view to assessing the ratio between the ACWR and the EWMA of the different EL, IL and SP variables and the injuries leading to training session or match time loss injuries recorded during the observation period.

Participants

All the 212 training sessions and matches between August and May in the 2018-2019 season were monitored for the 17 players of a senior women's amateur football team that competes in the women's División Preferente in Catalonia, with training three days a week lasting an hour and a half and one match a week. A total of 3,460 events were recorded as a result of calculating the total number of players participating in each session. The participants had a mean age of 22.87 (± 4.8), a mean weight of 58.08 (± 4.75) kg and a mean height of 164.9 (± 3.93) cm.

All the team members (players, coaches and managers) were informed about the purpose of the study and provided their consent for their data to be used. The use of the data observed the criteria of the Declaration of Helsinki, Fortaleza revision (2013).

Recording of the variables

The independent variables recorded in this study were the RPE for IL, SP (Solé, 2008) and exposure time in relation to training and competition for EL. For the dependent variables, time loss injuries (Fuller et al., 2006) that prevented players from participating in training sessions and matches were related to the injury rate and different acute:chronic load ratios.

The eligibility criteria for stabilising the control variables were that the study participants had no associated cardiac problems, that the training level was amateur (> 2 days of training minimum and < 4 days) and that they were active at sample randomisation time. The observation conditions were always on the same field and at the same time during training according to the timetable established by the institution. Medical check-ups were always conducted by the same medical staff.

For the monitoring of the EL variables, each player's exposure time in training and matches was recorded; for IL, the RPE was obtained after each session using the Google Forms application, individually and 15 to 30 minutes after the end of each session, whereas specificity was calculated post-session, assigning a value to the tasks and considering whether the proposal was generic (1-2), general (3-4), targeted (5-6), specific (7-8-9) or competitive (10) (Solé 2008), yielding an average value of the session for the entire team (Table 1). These monitored values were transferred to a file where the ACWR (4:16, 7:21, 7:28) and EWMA (4:16, 7:21, 7:28) ratios were calculated individually for each one of the variables recorded (exposure time, RPE and SP). The first number in the ratios is the numerator or average accumulated acute load over this number of days, while the second number is the denominator or average accumulated chronic load over this number of days. The total number of injuries was also recorded. The data were collected and analysed by the team's physical trainer.

Statistical analysis

After a descriptive analysis of central tendency, the normality of the sample was determined. Subsequently, using the Mann-Whitney test, the possible significant differences between the different ratios analysed and the injury or no injury variable were observed. The values of the ratios were subsequently grouped together to determine the possible level of association with the injuries, bearing in mind the variables' qualitative nature, and using the chi-squared test. The data were considered significant starting at $p < .05$ (Figure 1). The program used to perform the statistical analysis was JASP (The JASP Team, Amsterdam, Holland) version 11.1 for Mac.

Table 1
Parameters and variables recorded during the sessions with the study participants.

Internal load	
Ratings of perceived exertion (RPE, Borg 1990)	Scale CR-10
External load	
Total volume	Exposure time (minutes)
Training programme	
Specificity (Solé, 2008)	Generic (level 1-2). General conditioning work (continuous run, bicycle, etc.)
	General (level 3-4). Individual strength and injury prevention task, circuits without a ball
	Targeted (level 5-6). Tasks without opposition. Technical circuits, waves and combined actions
	Special (level 7-8-9) from 1-on-1 to 10-on-10. Basic tactical situations, waves with opposition, position or possession play, and line work with opposition
	Competitive (level 10). Training matches 11-on-11 or official competitions
Injury rate	
Injury (Fuller et al., 2006)	Time loss injury

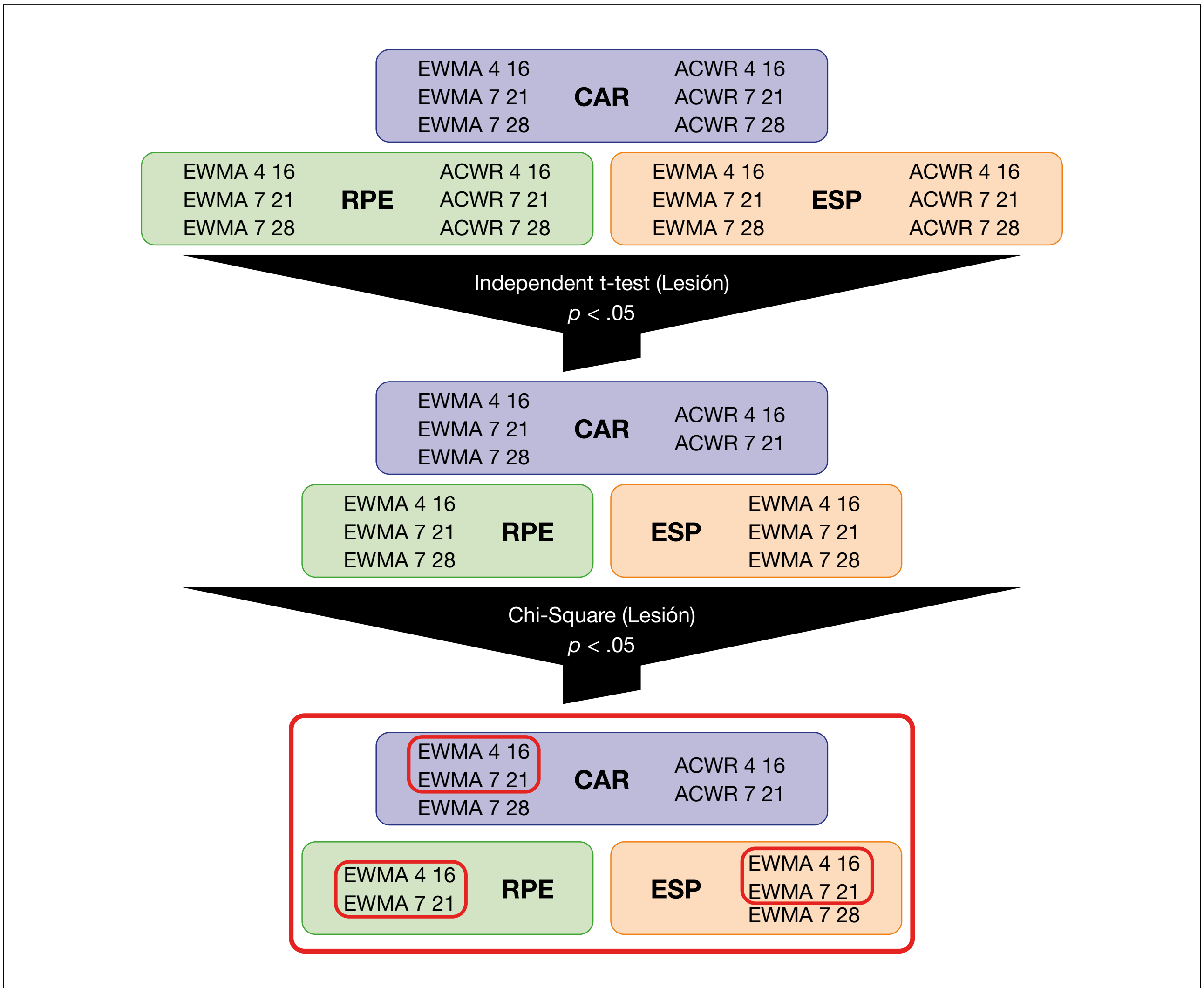

Figure 1
Statistical process with the analysed ratios of the study participants.

Table 2
Differences in the ACWR, EWMA ratios with regard to the injury or no injury variable in the study participants.

				95 % CI for the biserial correlation coefficient	
	W	*p*	Biserial correlation coefficient	Lower	Higher
RPE EW-MA 4 16	11820.00	< .01	-.42	-.60	-.19
RPE EW-MA 7 21	15437.50	.03	-.29	-.50	-.04
RPE EW-MA 7 28	14477.00	.05	-.26	-.48	-.01
RPE ACWR 4 16	45550.00	.59	.05	-.14	.24
RPE ACWR 7 21	39359.00	.93	.01	-.20	.21
RPE ACWR 7 28	37944.00	.40	.09	-.12	.30
SP EWMA 4 16	11645.50	< .01	-.43	-.60	-.21
SP EWMA 7 21	13877.00	< .01	-.36	-.56	-.12
SP EWMA 7 28	13223.00	< .01	-.33	-.54	-.08
SP ACWR 4 16	36537.50	.07	-.18	-.36	.01
SP ACWR 7 21	37067.50	.45	-.08	-.28	.13
SP ACWR 7 28	34943.50	.79	-.03	-.24	.19
LOAD EWMA 4 16	37657.00	< .01	-.28	-.45	-.09
LOAD EWMA 7 21	18206.00	< .01	-.59	-.71	-.43
LOAD EWMA 7 28	18364.00	< .01	-.53	-.67	-.35
LOAD ACWR 4 16	32760.00	.02	-.24	-.41	-.04
LOAD ACWR 7 21	29235.50	.02	-.25	-.43	-.04
LOAD ACWR 7 28	27421.00	.06	-.21	-.41	.01

Note. RPE: ratings of perceived exertion; SP: specificity; LOAD: load; EWMA: exponentially weighted moving average; ACWR: acute:chronic ratio. Significance $p < .05$

Results

The average values (+/- SD) per player obtained from the variables recorded during the 3,460 events were: for EL, 3365.226 +/- 1997.763 total minutes; for IL, an RPE of 6.305 +/- 1.689 per session; an SP of 6.852 +/- 2.302 per session; and a total of 12 time loss injuries were recorded, .011+/-.105 per player. The values of the ratios obtained were: RPE ACWR 4:16, 0.996 +/- 0.163; RPE ACWR 7:21, 0.998 +/- 0.121; RPE ACWR 7:28, 0.983 +/- 0.168; RPE EWMA 4:16, 0.962 +/- 0.502; RPE EWMA 7:21, 0.873 +/- 0.341; RPE EWMA 7:28, 0.857 +/- 0.366; ESP ACWR 4:16, 1.008 +/- 0.197; ESP ACWR 7:21, 1.003 +/- 0.143; ESP ACWR 7:28, 0.987 +/- 0.178; ESP EWMA 4:16, 0.988 +/- 0.496; ESP EWMA 7:21, 0.905 +/- 0.313; ESP EWMA 7:28, 0.885 +/- 0.342; CAR ACWR 4:16, 1.167 +/- 0.654; CAR ACWR 7:21, 1.067 +/- 0.463; CAR ACWR 7:28, 1.068 +/- 0.510; CAR EWMA 4:16, 0.977 +/- 0.582; CAR EWMA 7:21, 0.893 +/- 0.377; CAR EWMA 7:28, 0.885 +/- 0.411.

Statistical analysis

Given the non-normality of the sample, the Mann-Whitney test allowed us to determine significant differences ($p < .05$) with regard to the injury or no injury variable for the LOAD ACWR ratios and for the RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:28, 7:21), LOAD EWMA (4:16, 7:28, 7:21) and (4:16, 7:28) (Table 2) ratios, with an effect magnitude of between -.586 and -.262. No significant differences were found between the different positions analysed.

Subsequently, the values of the different ratios were grouped into different ranges with a difference greater than 1. The chi-squared test showed associations of all the previous ratios with injuries ($p < .05$) in LOAD ACWR and in RPE EWMA (4:16, 7:28, 7:21), SP EWMA (4:16, 7:21) and LOAD EWMA (4:16, 7:28, 7:21) and (4:16, 7:28), but not SP EWMA 7 28. With regard to the value of the ranges of the ratios obtained, the results show an association between the number of injuries and under the lower range of .7-.8, and of the upper range of 1.3-1.4, except for LOAD ACWR 4 16 (1.1) and LOAD EWMA 4 16 (1.2) where the upper range is 1.1 and 1.2, respectively (Table 3).

Table 3
Association for the ranges of ACWR and EWMA and the injury/no injury variable for the study participants.

Acute:chronic load ratio	X^2	Acute:chronic workload ratio ranges
RPE EWMA 4 16	< .01	< .8; .8-1.4; > 1.4
RPE EWMA 7 21	< .01	< .8; .8-1.3; > 1.3
RPE EWMA 7 28	.09	--
SP EWMA 4 16	< .01	< .8; .8-1.4; > 1.4
SP EWMA 7 21	.03	< .8; .8-1.3; > 1.3
SP EWMA 7 28	.04	< .8; .8-1.3; > 1.3
LOAD ACWR 4 16	.02	< .8; .8-1.1; > 1.1
LOAD ACWR 7 21	.03	< .8; .8-1.3; > 1.3
LOAD EWMA 4 16	.02	< .7; .7-1.2; > 1.2
LOAD EWMA 7 21	.00	< .7; .7-1.1; > 1.3
LOAD EWMA 7 28	.00	< .7; .7-1.3; > 1.3

Note. RPE: ratings of perceived exertion; SP: specificity; LOAD: load; EWMA: exponentially weighted moving average; ACWR: acute:chronic ratio. Significance $p <. 05$.

Discussion

This study's main finding of was the possible identification of acute:chronic workload ratios most highly related to injury rate. It transpires that EWMA may have a greater association with the number of injuries than the ACWR for both EL and IL, and even for SP, as well as in ratios for short (4:16) and longer periods (7:28). These results might concur with those presented by Foster et al. (2018), who state that using the EWMA may be more reliable for injuries, given that it presents greater sensitivity of calculation than the traditional ACWR (Griffin et al., 2020; Murray et al., 2016).

With regard to the variables used, we observed how the RPE identified as the IL variable in all the ratios established for EWMA could point to significant associations with the injuries of the players analysed. These results are related to those of Malone et al. (2017) and Fanchini et al. (2018), although these authors report their use of the ACWR with workload values resulting from the product of the EL by the IL, not with a single variable, as in our study and also as other authors present (Foster at al., 2018). Using this same method, albeit in a different sport (tennis), the use and analysis of the RPE as the sole variable for quantifying load may be a good indicator to use in calculating the acute:chronic ratio because of its significant relationship with the injury rate (Myers et al., 2019). Bearing in mind the scheduling of the training, SP returns significant associations through the use of the EWMA for the three types of variables (IL, EL, SP). This could provide further information about how the periodisation of an exercise similar to the actual match setting may be important in relation to how the player copes with the workload and its potential relationship with any injuries that may be sustained.

Both ACWR and EWMA, irrespective of whether they refer to EL, IL or SP, presented significant associations with regard to injuries, which could tell us that the acute:chronic workload ratio may be a valuable tool in load control (Griffin et al., 2020), taking the possibilities or the resources of each work group into account. Nevertheless, it is essential to nuance that this possible association is not synonymous with predictability, an interpretation that could lead to erroneous scientific conclusions (Griffin et al., 2020). In this context as well, the increase in the association of the ratios may be due to the connection of the different variables (EL and IL) that would define the load (Lolli et al., 2018), although this did not occur in the case presented here, since only one variable was used to calculate the ratio (EL, CI or SP) (Griffin et al., 2020).

With regard to the ratios, the three options proposed (4:16, 7:21 and 7:28) could also present significant associations, although the most significant ones were related to the load in long ratios (7:21 and 7:28), which are the ones used most often in group sports (Griffin et al., 2020). In a sport involving competitions every seven days, the use of this as an acute and chronic window might be justified as a tool applicable to this scheduling and competition model. Even so, and in contrast with this, significant associations can be seen through the use of four days as an acute window in all the variables for EWMA 4:16 and the EL ACWR 4:16 variable, which might be an indicator of the importance of managing acute loads and their possible influence on the injury rate (Carey et al., 2017) in this specific context.

On analysis of the groupings obtained, the ranges of the values of the ratios that might be associated with injuries fluctuate between .7-.8 in the lower range and 1.3-1.4 in the upper range. According to the initial proposal by Hulin et al. (2014) for EL or Gabbett (2018) (in ratios calculated for EL by IL), the range of 0.8 to 1.3 may lie in the lowest risk zone, given that that acute and chronic workload are approximately at the same magnitudes and there is therefore no overload or lack of training. The results do differ from other proposals in which RPE is used (Malone et al., 2017), where the ranges of the lowest risk of injury lie between the values of 1.00 and 1.25. In any event, the different options presented might be indicators of the specificity of each one of the variables, ratios and ranges in each sport and each team analysed. No value has sufficient magnitude to determine the boundary between the risk of injury or no injury. The cause of an injury is multifactorial and the complexity of the context is not congruent with this attempt at simplification (Gabbett, 2018).

The main limitation of this study is that kinematic variables are not monitored, since recording them would have made it possible to create a more justified profile of the values obtained in relation to EL. In turn, the fact that only time loss injuries were recorded reduces the number of records obtained, interfering in the magnitude of associations shown (Lolli et al., 2018), or preventing us from evaluating the possible influence according to playing position. Although it is a novel approach, it is essential to remember that using SP as a training programme element implicitly includes a subjective and random aspect. By exploring it, we have been able to assess its ultimate applicability. The RPE is a subjective value that may also have certain limitations (Impellizzeri et al., 2020; Buchheit, 2016), although its applicability in women's sport has also been confirmed (Piedra et al., 2020), and it has been used to calculate ACWR, presenting significant associations with injuries (Griffin et al., 2020). In any event, the limitations presented are inherent to amateur sport, in which limited economic resources preclude the use of certain technologies. For this reason, longitudinal explorations and studies are needed in the training context to assess their applicability.

In conclusion, in this specific context, acute:chronic workload ratios may be an applicable tool for controlling load in women's amateur football, given the possible relationship with the injury rate. The results yield a more positive assessment of the EWMA in view of its greater sensitivity. Finally, in relation to ratio ranges, the 0.8 to 1.3 range could be the value associated with the lowest injury rate. However, the interpretation of the results and their possible applicability should be limited to the contexts analysed.

Practical applications

Physical activity and sports sciences professionals, regardless of the available technology or the number of team members, can calculate and interpret load dynamics and indirectly improve the training and injury prevention process.

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Conflict of interests

The authors declare that they have no conflicts of interest and that no financing was received from any private or public entity for the project.

Future outlook

To continue this line of analysis, in future studies it might be interesting to observe whether the ratios also present associations by different types of injuries (Fuller et al., 2006). Similarly, including a kinematic study with the objective of relating it to the external load of training and player positions could be worthwhile.

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