Review

International Journal of Sports Science & Coaching

International Journal of Sports Science & Coaching
2023, Vol. 18(4) 1333–1341

DOI: 10.1177/17479541221104589
journals.sagepub.com/home/spo
Sage

Acute:chronic workload ratio and training monotony variations over the season in youth soccer players: A systematic review

Markel Rico-González[1], Rafael Oliveira[2,3,4], Francisco Tomás González Fernández[5] and Filipe Manuel Clemente[6,7,8]

Abstract

Since acute:chronic workload ratio and training monotony have been criticized as injury risk predictors, the use of intensity measures should be more oriented to understand the variations of intensity across the season. The aim of this systematic review is to summarize the main evidence about the acute:chronic workload ratio and training monotony variations over the season in youth soccer players. The search was made in PubMed, SPORTDiscus, and FECYT (Web of Sciences, CCC, DIIDW, KJD, MEDLINE, RSCI, and SCIELO) according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. From the 225 studies initially identified, 13 were fully reviewed, and their outcome measures were extracted and analyzed. Nine analyzed acute:chronic workload ratio, seven analyzed monotony, and four studies analyzed both acute:chronic workload ratio and monotony. Overall, the range values for acute: chronic workload ratio were 0.58–17.5 AU, while for monotony were 0.83–23.0 AU which showed a higher variability. Few studies showed an association between higher values of acute:chronic workload ratio and/monotony with injury risk or to prevent health problems. These measures could be used to understand the variations of the data through the in-season periods. However, caution is necessary due to the scarce studies performed in young soccer players.

Keywords

Football, injury risk, periodization

Reviewers: João Brito (Polytechnic Institute of Santarém, Portugal)
Mário Espada (Polytechnic Institute of Setúbal, Portugal)
Fernando Santos (Polytechnic Institute of Setúbal, Portugal)

[1]Department of Didactics of Musical, Plastic and Corporal Expression, University of the Basque Country, UPV-EHU, Leioa, Spain
[2]Research Center in Sport Sciences, Health Sciences and Human Development, Vila Real, Portugal
[3]Sports Science School of Rio Maior, Polytechnic Institute of Santarém, Rio Maior, Portugal
[4]Life Quality Research Centre, Rio Maior, Portugal
[5]Department of Physical Activity and Sport Sciences, Pontifical University of Comillas (Centro de Estudios Superiores Alberta Giménez), Palma, Spain
[6]Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, Viana do Castelo, Portugal
[7]Instituto de Telecomunicações, Delegação da Covilhã, Lisboa, Portugal
[8]Research Center in Sports Performance, Recreation, Innovation and Technology (SPRINT), Melgaço, Portugal

Corresponding author:
Markel Rico-González, Department of Didactics of Musical, Plastic and Corporal Expression, University of the Basque Country, UPV-EHU, Leioa, Spain.
Email: markel.rico@ehu.eus

Introduction

Characterization of the dose of the intensity imposed on soccer players become a popular topic in research and in practice scenarios.[1,2] In an environment of heterogeneity of the physiological and physical demands imposed by contextual factors as playing position and role, identification of intensity impact on players is determinant for understanding the effects of training planning.[3,4] The use of different instruments and measurement units is now well-implemented independently of the competitive level.[5] This is due to some of the instruments being subjective (e.g. rate of perceived exertion) and some of the objective instruments became low-cost (e.g. global positioning systems (GPS), inertial measurement units).[6]

Measures collected from monitoring systems allow determining the physiological and physical impact of training drills on the players.[7] However, aiming to use these measures for the interpretation of impact within and between sessions, some intensity measures have been proposed to determine how training principles have been achieved.[8] For example, in 1998, Carl Foster introduced two concepts[9]: (i) training monotony (TM); and (ii) training strain. These two concepts represented, in brief, the within-week variability of intensity (mean of intensity divided by the standard deviation of that week) and the strain (TM multiplied by the acute load, that is, the load an athlete is currently undergoing).[10] Later, Gabbett et al.[11] and Hulin et al.[12] introduced a intensity measure entitled acute: chronic workload ratio (ACWR) that represented the relationship of acute load (sum of intensities of the most recent week) by the rolling average of the last 28 days. Such an approach allowed to provide some indications about the progression of intensity across the weeks.

These intensity measures became popular in practice, namely claiming the "predictability capacity" of determining injury risk (in case of ACWR) or overtraining (in case of TM).[13] Although the attempt of turning these measures into "predictors," the existence of a relationship does not mean the existence of causality.[14] In the particular case of ACWR, and even after updates to the equation (e.g. using uncoupled or exponentially weighted moving average),[15,16] the concept itself was a target of serious scrutiny.[17–19] Thus, using ACWR or TM is not a "risk" itself, but the use of the intensity measures should be more oriented for analysis of training planning, more than for prediction of something else (e.g. injuries, illness).[17–19]

Some of the original research have centered the use of ACWR and TM to understand the variations of intensity across the season.[20,21] Most of the studies represent longitudinal approaches and try to understand how these intensity measures vary between periods of the season or based on specific contexts.[22] Interestingly, considering that youth soccer players (YSP) became more exigent and analyzed, a considerable number of articles centered the approach on YSP.[21,23] However, many of the research only reports single cases (one team), which seriously affects the generalizability of the findings. Possibly, by combining evidence of different original articles it is possible to understand how the intensity measures vary across the season and identify if any patterns can be identified in YSP. This may help coaches and strength and conditioning coaches to have some "guides" and comparative values. Thus, the aim of this systematic review is to summarize the main evidence about the ACWR and TM variations over the season in YSP.

Methods

Experimental approach to the problem

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[24–26] and guidelines for performing systematic reviews in sport sciences.[27] This review was not previously registered.

Information sources and search strategy

A systematic search was performed by two authors to identify relevant articles published before 1 May of 2021 (at 6:00 a.m.) in PubMed, SPORTDiscus, and FECYT (Web of Sciences, CCC, DIIDW, KJD, MEDLINE, RSCI, and SCIELO). The authors were not blinded to journal names or manuscript authors. Words used in the search strategy were: (soccer OR football) AND (acute:chronic OR ACWR OR monotony OR "workload ratio" OR "cumulative load" OR "week-to-week") NOT (rugby OR "Gaelic football" OR "American football")

Additionally, we manually searched the reference lists of the studies retrieved to identify other potentially eligible studies that were not captured by the electronic searches. Finally, we contacted an external expert to verify that our final list of references had not omitted any important study that should be included. Possible errata were searched for each included study.

Screening strategy and study selection

When these two authors completed their initial independent searches, they compared their results to ensure that they had found the same number of articles. Then, data extraction preparations were made in a Microsoft Excel sheet (Microsoft Corporation, Readmon, WA, USA) in accordance with the Cochrane Consumers and Communication Review Group's data extraction template.[28] The Excel spreadsheet was used to assess each study vis a vis the inclusion/exclusion requirements for study selection and for entering all pertinent data for each study so that all the study records were stored in this data sheet.

The inclusion criteria for selecting studies are given in Table 1.

Extracted information and variables of interest

The following information was extracted from the included original articles: sample, study duration, variable, ACWR, monotony, and concluding remarks.

Methodological assessment

Methodological quality was assessed by two authors (R.O. and M.R.G.) using the methodological index for non-randomized studies (MINORS).[29] The global ideal score being 16 for non-comparative studies. MINORS consists of 12 items, four of which are only applicable to comparative studies which was not the case of the included studies with one exception that will described further. Thus, only eight items were applied. Each item is rated as 0 when

Table 1. Inclusion/exclusion criteria for selecting articles.

Item	Inclusion criteria	Exclusion criteria
Population	Studies developed with youth soccer players with no injury or illness reported	–
Intervention/ exposure	Studies that extracted ACWR or TM measured from recorded training load during training sessions	–
Comparison/ control	–	–
Outcome	Studies that reported the ACWR and training monotony variations over the season	
Study design	Test was conducted in soccer's training	Test was not conducted in soccer or it was done during official matches
Other	Only original and full-text studies written in English	Written in another language than English. Other article types than original (e.g. reviews, letters to editors, trial registrations, proposals for protocols, editorials, book chapters, and conference abstracts)

Note: ACWR: acute:chronic workload ratio; TM: training monotony.

the criterion is not reported in the article, 1 if reported but not sufficiently fulfilled, or 2 when adequately met. Higher scores indicate good methodological quality of the article and low risk of bias. The highest possible score is 16 for non-comparative studies. MINORS has yielded acceptable inter- and intra-rater reliability, internal consistency, content validity, and discriminative validity.[29,30]

In addition, one study[31] was a cluster randomized controlled trial and once MINORS is a proper methodological tool to randomized studies, Physiotherapy Evidence Database (PEDro) scale was used.[32] This scale comprises 11 questions with yes or no answers (yes = 1; no = 0), providing a total score which ranges between 0 (poor methodological quality) and 10 (excellent methodological quality). The first item of the scale does not refer to the methodological quality of the randomized controlled trials but rather its external validity, which is excluded from the total score.

The Van Tulder et al.[33] criteria was applied which means that if the study achieved a score of 6 or more, is considered level 1 (high methodological quality) (6–8: good, 9–10: excellent) and a score of 5 or less is considered level 2 (low methodological quality) (4–5: moderate; <4: poor).

Results

Study identification and selection

The searching of databases identified a total of 225. These studies were then exported to reference manager software (EndNote™ X9, Clarivate Analytics, Philadelphia, PA, USA). Duplicates (109 references) were subsequently removed either automatically or manually. The remaining 116 were screened for their relevance based on titles and abstracts, resulting in the removal of a further 59 studies. Following the screening procedure, 57 articles were selected for in-depth reading and analysis. After reading full texts, 13 studies were included in the qualitative synthesis (Figure 1).

Methodological quality

The overall methodological quality of the studies can be found in Table 2 while the study of Dalen-Lorentsen et al.[31] assessed through the PEDro scale obtain a "yes" response for: eligibility, random allocation, baseline comparability, blind assessors, intention-to-treat analysis, between-group comparisons, point estimates, and variability criteria. The following criteria obtain a "no" response: concealed allocation, blind subjects, blind therapists, adequate follow-up. Considering that eligibility criteria item does not contribute to total score, this study obtained a total score of 6 points which is considered a good methodological quality.

Characteristics of individual studies

The characteristics of studies that reported ACWR and/or monotony were detailed in Table 2. From a total of 13, 9 studies analyzed ACWR,[21,23,31,34,36,37,39,40,42] 7 studies analyzed monotony,[21,23,35,37,38,40,41] in which 4 studies analyzed both ACWR and monotony.[21,23,37,40]

There were different purposes. Some studies analyzed the relationship between both intensity measures and injuries.[34,36,39,40,42] One study analyzed association between the intensity measures and health condition.[43] Two studies analyze monotony and its relationship with performance.[37,41] The remaining studies described both intensity measures across different periods of the season (Table 3).[21,23,35,38]

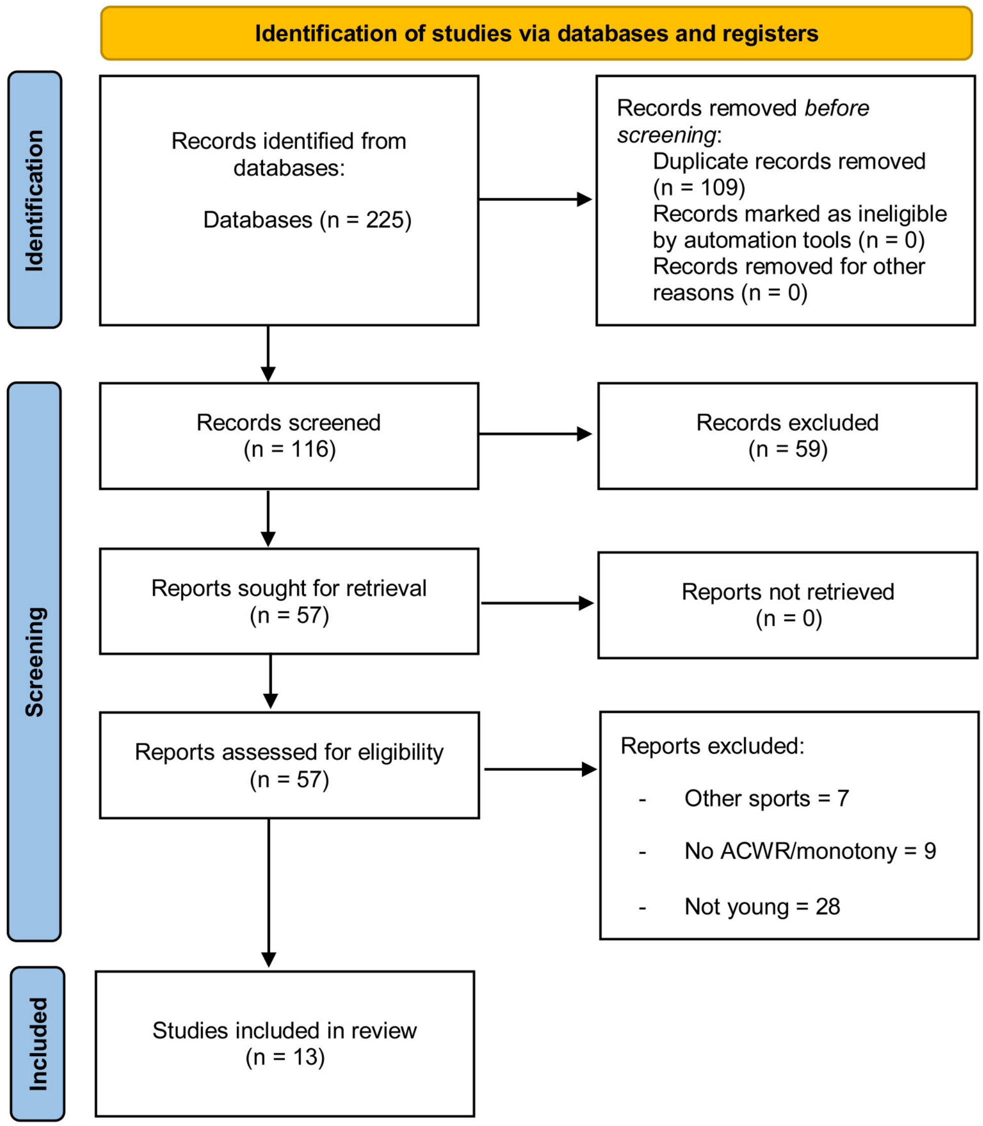

Figure 1. Flow diagram of the selection of studies.

Discussion

This systematic review aimed to summarize the main evidence about the ACWR and TM variations over the season in YSP. The systematic review revealed variability of outcomes due to the scarce studies performed in young soccer players.

Chronic workload ratio

ACWR has been explored in different ways, but mainly centered in the variations of intensity across the season. The variability of studies found in relation of register implementation[20,21] showed differences depending on the processing time. This supports previous evidence showing studies performed since one to five seasons (one season with session rating of perceived exertion (session RPE) measures[39]; two seasons with GPS measures,[42] and five seasons with s-RPE measures[34]). However, the studies performed with s-RPE did not revealed association with injury risk but crucially, the use of GPS measures appear to find relationship with non-contact and contact injury risks. These findings extend previous research on ACWR performed in professional soccer[19] and do not clarify all doubts in this topic. The gender does not appear significant additional influence.[36] In fact, this study suggest that higher acute training load could be associated with increased production of injuries and illness risk in YSP. In the same line, other independent variable of ACWR was the training intensity, reflexed in different studies with s-RPE. However, s-RPE does not seem to be a good variable to predict injuries.[31,34,36,39] Crucially, other research found

Table 2. Methodological assessment of the included studies.

Reference	1	2	3	4	5	6	7	8	Score
Delecroix et al.[34]	1	2	1	2	2	2	1	2	13/16
Borges et al.[35]	2	2	2	2	1	2	2	2	15/16
Watson et al.[36]	1	2	2	2	1	2	2	2	14/16
Nobari et al.[37]	1	2	2	2	1	2	2	2	14/16
Houtmeyers et al.[38]	2	2	1	1	0	2	2	1	11/16
Dalen-Lorentsen et al.[31]	2	2	2	1	0	2	2	2	13/16
Raya-González et al.[39]	2	2	2	2	1	2	1	2	14/16
Nobari et al.[21]	2	2	2	2	1	2	2	1	14/16
Nobari et al.[23]	1	2	2	2	1	2	1	2	13/16
Arazi et al.[40]	2	2	2	2	1	2	2	1	14/16
Figueiredo et al.[41]	1	2	2	2	1	2	2	0	12/16
Bowen et al.[42]	1	2	2	2	1	2	2	2	14/16
Dalen-Lorentsen et al.[43]	1	2	2	2	1	2	2	1	13/16

Note: *The MINORS checklist asks the following information (2 = high quality; 1 = medium quality; 0 = low quality). 1: clearly defined objective. 2: inclusion of patients consecutively. 3: information collected retrospectively. 4: assessments adjusted to objective. 5: evaluations carried out in a neutral way. 6: follow-up phase consistent with the objective. 7: dropout rate during follow-up less than 5%. 8: appropriate statistical analysis.

associations with injury occurrence from different models used.[40] In this sense, if s-RPE variable was added to control monotony may achieve a high accuracy in prediction.[37,41] In addition, the different protocols applied and methodological approach showed conflicting results.[43] For this reason, according to the current findings more research will be necessary to elucidate the underlying role of s-RPE in ACWR. Indeed, this would agree with the study of Bowen et al.[42] that found an association between ACWR and higher injury risk. In any case, s-RPE could be linked with time of familiarization that young soccer players have with this tool. Although, it is noteworthy that previous research suggest that the time between the assessment after of training also was a key factor to determine the accuracy of ACWR values.[44]

Monotony

As noted above, in the case of TM, the existence of a relationship does not mean the existence of causality to determining injury risk (see Afonso et al.[13]). This is the reason why the intensity measures, monotony in this case, should be used to control the training and individual's differences and not for looking for prediction which does not prove current relationship between measures. Many of the different findings have been linked to duration of studies. In fact, as mentioned earlier the intensity measures vary between periods[22] and therefore, thought it must deepen its understanding. For this reason, the variability on time of protocols or measures application could cause different approach of interpretations of the data. For example, all the analyses were performed only with one team with a sample greater than 9 at lower than 30. Consequently, the variability of results starts due to different protocols and sample used. In this sense, other study found difference between-subject variations that suggest individual variability through s-RPE, that as mentioned before, might be due to the participants' age.[35] On the one hand, also was found higher values in TD in young soccer players (U19) with respect to first team players.[38] On the other hand, studies of Nobari et al.[21,23] showed the variations in the middle of in-season and the higher TM that coincide with higher and lower values of ACWR. In fact, other findings encountered by Figueiredo et al.[41] reflected higher values of TM that were associated with lower increased in performance. It becomes a model that has a relationship with the behavior of soccer player during a season (see Silva et al.[45] for more information). Last, Arazi et al.[40] and Nobari et al.[37] reflected that ACWR together TM should be used to better explain the physical capacities. Despite that, as Afonso et al.[13] suggest the integrations of s-RPE with GPS data provide a better approach to knowledge about TM.

Practical implications and future research

The results of the present systematic review emphasize in a potential finding that deepening about the variations of intensity across the season. In other words, the use of monotony and ACWR may be useful to analyze variations and progression of the intensity across the weeks/periods or season. In fact, the results guarantied an important research topic in this population and contribute to demonstrating the evidence of ACWR and TM variations as a possible predictor that is lightly associated with injury risks. It also contributes to the research that recollected data, testing assumptions, and looking for physiological and behaviors patterns in young soccer players. Future studies may analyze if the understanding of the concepts of ACWR and TM for part of young soccer players may induce more favorable effects for receiving the intensity. In addition, young soccer players should be responsible for the intensity perception and create different instruments that connected both measures.

A practical application of this review shows the evidence on ACWR and TM in improvement of intensity control and determining the most adequate and practicable physical condition strategies by technical and physical staff in order to organize the more important physical contents in face of weekly competition. In sum, this review provides key information about the intensity control in young soccer players, as the factors that have been monitored can be taken into account to select the best player needed considering his individual fitness level in order to improve the overall team performance.

Table 3. Characteristics, summary, and evidence about ACWR and monotony studies.

Ref.	Gender|Age	*N*	Duration	Variables	ACWR (AU)	Monotony (AU)	Concluding remarks
Delecroix et al.[34]	M U19: 16.8 ± 0.9 U21: 20.1 ± 0.3	*N*: 112 U19 = 52 U21 = 70	5-seasons	s-RPE	U19 4 weeks 1.01 (0.96–1.07) 3 weeks 1.00 (0.95–1.06) 2 weeks 0.99 (0.90–1.09) Week to week changes 1.00 (0.96–1.04) U21 4 weeks 0.89 (0.71–1.13) 3 weeks 0.88 (0.66–1.16) 2 weeks 0.86 (0.58–1.29) Week to week changes 1.00 (0.95–1.06)	NA	ACWR showed no association with injury in U19 and U21 categories
Borges et al.[35]	M U20: 17.9 ± 0.6	*N*: 30	5-weeks	s-RPE	NA	1.9 ± 0.8–2.6 ± 0.6	Significant between-subject variations were found in TM what suggests individual variability through s-RPE
Watson et al.[36]	F U16: 15.5 ± 1.6	*N*: 75	20-weeks In-season	s-RPE	~0.8–1.25	NA	Acute load is an independent predictor of injury, while high chronic load is associated with an increased risk of illness
Houtmeyers et al.[38]	M U19: 17.6 ± 0.6	*N*: 9	33-weeks In-season	TD TD 12–15 km/h TD 15–20 km/h TD 20–25 km/h TD >25 km/h	NA	1.55 ± 0.22 1.04 ± 0.12 0.96 ± 0.12 0.90 ± 0.21 0.83 ± 0.44	TM calculated through TD showed to be higher in U19 players compared to first team players
Dalen-Lorentsen et al.[31]	M: 17.5 ± 0.7 F: 17.5 ± 1.3	*N*: 86 M: 47 F: 39	16-weeks In-season	s-RPE	Non-extractable data.	NA	The load management intervention was not successful for prevent health problems
Raya-González et al.[39]	M U19: 18.6 ± 0.6	*N*: 22		s-RPE	Non-extractable data.	NA	No association was found for ACWR calculated through s-RPE with respect to injury occurrence. It was also showed poor ability to predict injury occurrence
Nobari et al.[21]	U16: 15 ± 0.2	*N*: 29	20-weeks In-season	s-RPE	0.90–1.14	1.06–1.19	The highest ACWR values were verified in the middle of in-season and the lowest values in the beginning of the in-season
Nobari et al.[23]	U17: 16.1 ± 0.2	*N*: 21	36-weeks In-season	s-RPE	~1.05–1.10	~1.0–1.3	Middle-season was the period with higher TM variability while early season was the period with higher and lower values of ACWR
Arazi et al.[40]	M U18: 17.1 ± 0.7	*N*: 22	4-weeks In-season	s-RPE	RA = ~0.8–1.2 EWMA = ~0.9–1.3	2.3–5.0	ACWR-EWMA model showed to be more sensitive than

(continued)

Table 3. (continued)

Ref.	Gender|Age	*N*	Duration	Variables	ACWR (AU)	Monotony (AU)	Concluding remarks
							ACWR-RA to identify non-contact injury occurrence
Figueiredo et al.[41]	M U15: 14.33 ± 0.3 U17: 16 ± 0.7	*N*: 17 U15: 9 U17: 8	4-weeks Pre-season	s-RPE	NA	U15 3.34 ± 0.46–3.75 ± 0.69 U17 3.2 ± 0.2–3.5 ± 0.5	Both categories showed that higher TM values were associated with lower increased in performance
Bowen et al.[42]	M U18: 17.3 ± 0.9	*N*: 32	2 full-seasons	TD HSD ACC Player Load	0.04–1.76 (Min-max) 0.00–1.89 0.05–1.77 0.03–1.76	NA	ACWR through GPS measures were significantly related to non-contact and contact injury risk. Higher workloads were associated with higher injury risks
Dalen-Lorentsen et al.[43]	M: 17.5 ± 0.7 F: 17.5 ± 1.3	N: 86 M: 47 F: 39	16-weeks In-season	s-RPE	Non-extractable data	NA	The relationship between ACWR and health problems was highly dependent on methodological approach
Nobari et al.[37]	M U16: 1.9 ± 0.3	*N*: 23	20-weeks In-season	s-RPE	17.5 ± 0.3 CI: 17.4 to 17.7	TM = 23 ± 0.4 CI: 22.8 to 23.2	It was suggested that ACWR and TM values can be used to better explain the physical capacities of young players

Note: ACC: acceleration; AU: arbitrary units; ACWR: acute:chronic workload ratio; CI: confidence intervals; EWMA: exponentially weighted moving average; F: female; GPS: global positioning system; HSD: high-speed running; M: male; NA: non-applied; RA: rolling average; s-RPE: session rated perceived exertion; TD: total distance; TM: training monotony; U: under.

Study limitations

This systematic review has some limitations. On the one hand, the small number of included articles and the participants involved (15–21 years old), has highlighted not only the differences between categories, but also the different duration of the experiments. For this reason, this systematic work should be faced as a limiting factor for the generalization of scientific evidence. Additionally, most studies are the tact of being limited to case reports of one only team. Nevertheless, it should be noted that the findings are relevant partly due to the sample of young soccer players since most previous research have been done on professional soccer player.

Conclusions

This systematic review investigated the main evidence about the ACWR and TM variations over the season in YSP. There is no clear information about whether ACWR and TM variations are a possible predictor associated with injury risks. In fact, only a few studies were associated. In this sense, the heterogeneity in the designs, age, categories, and durations of the studies and the small number of works carried out in young soccer player are the main reason for the lack of conclusive results.

This systematic review highlights the importance of training planning from ACWR and TM and its impact on young soccer player mainly in longitudinal studies to minimize the number of injuries a long of season.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Markel Rico-González https://orcid.org/0000-0002-9849-0444
Rafael Oliveira https://orcid.org/0000-0001-6671-6229
Francisco Tomás González Fernández https://orcid.org/0000-0002-1480-7521
Filipe Manuel Clemente https://orcid.org/0000-0001-9813-2842

References

1. Fox JL, Stanton R, Sargent C, et al. The association between training load and performance in team sports: a systematic review. *Sports Med* 2018; 48: 2743–2774.
2. Verstappen S, van Rijn RM, Cost R, et al. The association between training load and injury risk in elite youth soccer players: a systematic review and best evidence synthesis. *Sports Med – Open* 2021; 7: 6.
3. Chena M, Morcillo JA, Rodríguez-Hernández ML, et al. The effect of weekly training load across a competitive microcycle on contextual variables in professional soccer. *IJERPH* 2021; 18: 5091.
4. Guerrero-Calderón B, Klemp M, Castillo-Rodriguez A, et al. A new approach for training-load quantification in elite-level soccer: contextual factors. *Int J Sports Med* 2020; 42(8): 716–723.
5. Weston M. Training load monitoring in elite English soccer: a comparison of practices and perceptions between coaches and practitioners. *Sci Med Football* 2018; 2: 216–224.
6. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med* 2014; 44: 139–147.
7. Impellizzeri FM, Marcora SM and Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol Perform* 2019; 14: 270–273.
8. Akenhead R and Nassis GP. Training load and player monitoring in high-level football: current practice and perceptions. *Int J Sports Physiol Perform* 2016; 11: 587–593.
9. Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exercise* 1998; 30: 1164–1168.
10. Andrade R, Wik EH, Rebelo-Marques A, et al. Is the acute: chronic workload ratio (acwr) associated with risk of time-loss injury in professional team sports? A systematic review of methodology, variables and injury risk in practical situations. *Sports Med* 2020; 50: 1613–1635.
11. Gabbett TJ, Hulin BT, Blanch P, et al. High training workloads alone do not cause sports injuries: how you get there is the real issue. *Br J Sports Med* 2016; 50: 444–445.
12. Hulin BT, Gabbett TJ, Lawson DW, et al. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med* 2016; 50: 231–236.
13. Afonso J, Nakamura FY, Canário-Lemos R, et al. A novel approach to training monotony and acute-chronic workload index: a comparative study in soccer. *Front Sports Act Living* 2021; 3: 661200.
14. Stovitz SD, Verhagen E and Shrier I. Distinguishing between causal and non-causal associations: implications for sports medicine clinicians. *Br J Sports Med* 2019; 53: 398–399.
15. Williams S, West S, Cross MJ, et al. Better way to determine the acute:chronic workload ratio? *Br J Sports Med* 2017; 51: 209–210.
16. Windt J and Gabbett TJ. Is it all for naught? What does mathematical coupling mean for acute:chronic workload ratios? *Br J Sports Med* 2019; 53: 988–990.
17. Enright K, Green M, Hay G, et al. Workload and injury in professional soccer players: role of injury tissue type and injury severity. *Int J Sports Med* 2020; 41: 89–97.
18. Fanchini M, Rampinini E, Riggio M, et al. Despite association, the acute:chronic work load ratio does not predict non-contact injury in elite footballers. *Sci Med Football* 2018; 2: 108–114.
19. Impellizzeri FM, Woodcock S, Coutts AJ, et al. What role do chronic workloads play in the acute to chronic workload ratio? Time to dismiss acwr and its underlying theory. *Sports Med* 2021; 51: 581–592.
20. Clemente FM, Silva R, Chen Y-S, et al. Accelerometry-workload indices concerning different levels of participation during

congested fixture periods in professional soccer: a pilot study conducted over a full season. *IJERPH* 2021; 18: 1137.
21. Nobari H, Aquino R, Clemente FM, et al. Description of acute and chronic load, training monotony and strain over a season and its relationships with well-being status: a study in elite under-16 soccer players. *Physiol Behav* 2020; 225: 113117.
22. Clemente F, Silva R, Ramirez-Campillo R, et al. Accelerometry-based variables in professional soccer players: comparisons between periods of the season and playing positions. *Biol Sport* 2020; 37: 389–403.
23. Nobari H, Alves AR, Haghighi H, et al. Association between training load and well-being measures in young soccer players during a season. *IJERPH* 2021; 18: 4451.
24. Page MJ, McKenzie JE and Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Br Med J* 2021; n71.
25. Page MJ, McKenzie JE, Bossuyt PM, et al. Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement. *J Clin Epidemiol* 2021; 134: 103–112.
26. PRISMA-S Group, Rethlefsen ML, Kirtley S, et al. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. *Syst Rev* 2021; 10: 39.
27. Rico-González M, Pino-Ortega J, Clemente FM, et al. Guidelines for performing systematic reviews in sports science. *Biol Sport* 2022; 39: 463–471.
28. Group CCCR. Data Extraction Template for Included Studies.
29. Slim K, Nini E, Forestier D, et al. Methodological index for non-randomized studies (minors): development and validation of a new instrument. *ANZ J Surg* 2003; 73: 712–716.
30. Kim SY, Park JE, Lee YJ, et al. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *J Clin Epidemiol* 2013; 66: 408–414.
31. Dalen-Lorentsen T, Bjørneboe J, Clarsen B, et al. Does load management using the acute:chronic workload ratio prevent health problems? A cluster randomised trial of 482 elite youth footballers of both sexes. *Br J Sports Med* 2021; 55: 108–114.
32. Maher CG, Sherrington C, Herbert RD, et al. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther* 2003; 83: 713–721.
33. van Tulder M, Furlan A, Bombardier C, et al. Updated method guidelines for systematic reviews in the cochrane collaboration back review group. *Spine* 2003; 28: 1290–1299.
34. Delecroix B, Delaval B, Dawson B, et al. Workload and injury incidence in elite football academy players. *J Sports Sci* 2019; 37: 2768–2773.
35. Borges TO, Moreira A and Thiengo CR. Training intensity distribution of young elite soccer players. *Rev Bras Cineantropom Hum* 2019; 11.
36. Watson A, Brickson S, Brooks A, et al. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. *Br J Sports Med* 2017; 51: 194–199.
37. Nobari H, Tubagi Polito LF, Clemente FM, et al. Relationships between training workload parameters with variations in anaerobic power and change of direction status in elite youth soccer players. *IJERPH* 2020; 17: 7934.
38. Houtmeyers KC, Jaspers A, Brink MS, et al. External load differences between elite youth and professional football players: ready for take-off? *Sci Med Football* 2021; 5: 1–5.
39. Raya-González J, Nakamura FY, Castillo D, et al. Determining the relationship between internal load markers and noncontact injuries in young elite soccer players. *Int J Sports Physiol Perform* 2019; 14: 421–425.
40. Arazi H, Asadi A, Khalkhali F, et al. Association between the acute to chronic workload ratio and injury occurrence in young male team soccer players: a preliminary study. *Front Physiol* 2020; 11: 608.
41. Figueiredo DH, Figueiredo DH and Matta MdO. Associação entre parâmetros de carga interna de treinamento e desempenho físico em atletas de futebol durante a pré-temporada. *Revista Brasileira de Prescrição e Fisiologia do Exercício* 2018; 12: 1078–1085.
42. Bowen L, Gross AS, Gimpel M, et al. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *Br J Sports Med* 2017; 51: 452–459.
43. Dalen-Lorentsen T, Andersen TE, Bjørneboe J, et al. A cherry tree ripe for picking: the relationship between the acute: chronic workload ratio and health problems. *J Orthop Sports Phys Ther*. Epub ahead of print 7 March 2020. DOI: 10.31236/osf.io/nhqbx.
44. Schmeck A, Opfermann M, van Gog T, et al. Measuring cognitive load with subjective rating scales during problem solving: differences between immediate and delayed ratings. *Instr Sci* 2015; 43: 93–114.
45. Silva R, Clemente FM, González-Fernández FT, et al. Weekly variations of short-duration maximal jumping performance in soccer players: exploring relationships with accumulated training load and match demands. *Front Physiol* 2021; 12: 690353.