

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

Markel Rico-González<sup>1,2</sup>, Francisco Tomás González Fernández<sup>3</sup>, Rafael Oliveira<sup>4,5</sup> and Filipe Manuel Clemente<sup>6,7</sup>

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## Abstract

Acute: chronic workload ratio (ACWR) and training monotony have been criticized as injury risk predictors. Therefore, the use of intensity measures should be oriented to understand the variations of intensity across the season. The aim of this systematic review is to summarize the main evidence about the ACWR and training monotony variations over the season in professional soccer players. The search was made in PubMed, SPORTDiscus, and FECYT according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. From the 225 studies initially identified, 27 were fully reviewed, and their outcome measures were extracted and analyzed. Existing literature revealed a variety of designs, ACWR and training monotony ranges, variables assessed and durations of the studies. Overall, the range values for ACWR were 0.4–3.39 AU, while those focused on monotony were 0.49–5.7 AU. Regarding ACWR, the ratios located around 0.85–1.25 could predict lower risk values and ratios around  $\geq 1.50$  could predict higher risk values. On the contrary, with respect to training monotony, the ratios are approximately between 0.5 and 2.00 (low values in the preseason and low competition weeks and high values when soccer players are in highly scheduled competition weeks). Nevertheless, ACWR and training monotony methods should be addressed and considered based on their real value before using this indicator to reduce injury risk. In fact, the data did not conclusively define injured and non-injured players. For this reason, utilizing standardized approaches will allow for more precise conclusions about professional soccer players.

## Keywords

Football, performance, periodization, load management, injury, technology, global positioning systems, training, team sports, workload

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## Introduction

Professional soccer players are experiencing challenging times, in which the more heavily scheduled weeks have been seen to constitute a source of biological stress.<sup>1,2</sup> For that reason, monitoring and assessment have become even more important to identify the impact of training and match loads on players' well-being and readiness.<sup>3</sup> Although relationships between load and well-being are not consistent,<sup>4</sup> the impact of load on readiness has been shown to be directly linked with recovery and fatigue mechanisms.<sup>2,5</sup>

Monitoring training loads has become popular and one of the main practices for supporting the overall training process.<sup>6,7</sup> Due to the implementation of

<sup>1</sup>Department of Didactics of Musical, Plastic and Corporal Expression, University of the Basque Country, UPV-EHU, Leioa, Spain

<sup>2</sup>Biovetmed & Sportsci Research Group, Department of Physical Activity and Sport, Faculty of Sport Sciences, University of Murcia, San Javier, Murcia, Spain

<sup>3</sup>Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain

<sup>4</sup>Life Quality Research Centre, Rio Maior, Portugal

<sup>5</sup>Sports Science School of Rio Maior, Polytechnic Institute of Santarém, Rio Maior, Portugal

<sup>6</sup>Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, Viana do Castelo, Portugal

<sup>7</sup>Instituto de Telecomunicações, Delegação da Covilhã, Lisboa, Portugal

## Corresponding author:

Markel Rico-González, Department of Didactics of Musical, Plastic and Corporal Expression, University of the Basque Country, UPV-EHU, Leioa 48940, Spain.

Email: markel.rico@ehu.eus

different instruments (e.g. global positioning systems, inertial measurement units, rates of perceived exertion) it is becoming easier to determine the exact intra- and inter-week variations of load on the players.<sup>8</sup> Although not new, as the implementation of workload measures has progressively increased, so has the desire to identify how the load varies from player to player and the expectation to anticipate players' responses.<sup>9,10</sup>

Monitoring practices are expected to help optimize the training process and improve recovery strategies.<sup>11</sup> Additionally, monitoring helps coaches to be attentive to signals of overreaching behavior or possible increases in injury risk.<sup>12</sup> For example, some studies suggest that fatigue and incomplete recoveries may play a role in decreasing peak eccentric muscle torque and functional strength ratio with potentially harmful consequences for the predisposition to hamstring injuries.<sup>13,14</sup> Another original piece of research suggested that fatigue may impair sprinting performance and the kinematics of running, ultimately resulting in alterations in technique and increases in predisposition to hamstring strain injury.<sup>15</sup> Monitoring processes are also part of daily work in training, aiming to understand if players' exposure to severe increases or decreases in load may also affect their injury risk.<sup>16</sup>

Different measures are currently used for monitoring players. Monitoring load is often grouped into two categories: (i) internal load and (ii) external load.<sup>17</sup> The external load is related to the physical, locomotor, and/or mechanical demands (e.g. distance covered at different speed thresholds, accelerations, and decelerations) that a given training drill imposes on the player.<sup>17</sup> The internal load represents the psychophysiological responses (e.g. heart rate, rate of perceived exertion) associated with the corresponding external load.<sup>17</sup> Although related, the magnitude of the relationship between external and internal load measures is variable-dependent and mode training-dependent. For example, the rate of perceived effort multiplied by the session time (sRPE) or training impulse calculated using heart rate commonly shows a strong association with total distance or frequency of accelerations, although not with sprinting or high-speed running distances.<sup>18</sup>

Given the number of daily measures collected in sports training while using different instruments, some authors proposed workload measures that may help to understand the intra-individual dynamics occurring within sessions or within and between weeks. Examples of workload measures such as training impulse, first introduced by Banister and Calvert<sup>19</sup> and then adjusted by Edwards,<sup>20</sup> or training monotony and strain introduced by Foster,<sup>21</sup> represent some of the most common workloads that use the measures extracted from the instruments to determine intra-session (Banister or Edward's training impulse) or intra-week impact of load (training monotony – which represents the mean of the load by the standard deviation, and training strain – which multiplies the monotony by the sum of the weekly load). Lately, the introduction of acute:

chronic workload measurements (ACWR) has provided a new view of the progression of loads across the weeks, with respect to the former load applied.<sup>22,23</sup> The classical division of acute load (sum of load during current week) by the 28-day rolling average (chronic load),<sup>22,23</sup> has been updated by the uncoupled version (in which the most recent week is not considered in the chronic load)<sup>24</sup> and integrates the exponentially weighted moving average.<sup>25</sup>

Despite many attempts to establish a direct relationship between ACWR and training monotony and some events, such as injuries or illness, these relationships are far from representing cause and effect.<sup>26</sup> In the case of ACWR, some recent criticisms have been made on the abusive use of the workload measure to “predict” injury risk.<sup>27–29</sup> Recently, the suggestion is reframing the conceptual model of ACWR,<sup>29</sup> a similar approach is needed for training monotony because variability should be understood beyond load, but also considering load orientation.<sup>30</sup> Thus, more than looking for workload measures as “predictors” of injury, they should be seen as indicators of how the training load has been administered following the training principles of progression (inter-week variation) or variability (intra-week variation).

Based on the above, some longitudinal studies in soccer have been reporting seasonal variations of workload measures. These reports allow one to determine how training planning has been implemented in soccer, and what the impact has been on the players. However, one of the limitations of these studies is the fact of being limited to single cases (one team). Thus, only by conducting a systematic review is it possible to generalize the evidence and determine how training load varies across the season in different professional soccer teams and contexts. Thus, the current systematic review aims to summarize the main evidence about the ACWR and training monotony variations over the season in professional soccer players.

## 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<sup>31–33</sup> and guidelines for performing systematic reviews in sport sciences.<sup>34</sup> This review was not previously registered.

### *Eligibility criteria*

The screening of the title, abstract and reference list of each study was completed to locate potentially relevant studies. Additionally, the researchers reviewed the full version of the included papers in detail to identify articles that met the selection criteria. An additional search within the reference lists of the included records was conducted to retrieve additional relevant studies.

Possible errata for the included articles were considered. The articles were included following these inclusion criteria.

### *Information sources and search*

PubMed, SPORTDiscus, and FECYT (Web of Sciences, CCC, DIIDW, KJD, MEDLINE, RSCI, and SCIELO) were searched for relevant publications prior to May 1, 2021. Keywords and synonyms were entered in various combinations in the title, abstract or keywords: (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, the reference lists of the studies retrieved were manually searched to identify potentially eligible studies not captured by the electronic searches. Possible errata were searched for each included study.

### *Data extraction*

A data extraction was prepared in Microsoft Excel sheet (Microsoft Corporation, Redmond, WA, USA) in accordance with the Cochrane Consumers and Communication Review Group’s data extraction template.<sup>35</sup> The Excel sheet was used to assess inclusion requirements and subsequently tested for all selected studies. When the information from each article found was downloaded, it was automatically classified in the Excel sheet in five different columns (database, title, authors, journal, and year). The duplicates were selected and excluded before the analysis of abstracts and full texts. Then, the articles were codified with different numbers according to inclusion/exclusion criterion. Therefore, full text articles excluded, with reasons, were recorded. All the records were stored in the excel spreadsheet.

### *Data items*

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

### *Methodological assessment*

A methodological assessment process was performed using an adapted version of the STROBE assessment criteria,<sup>36</sup> when seeking studies eligible for inclusion in this study. Each article was assessed based on 10 specific criteria (see Table 2). Any disagreement was discussed and solved by consensus decision. Each item was evaluated using numerical characterization (1 = completed; and 2 = non-completed). As suggested by O’Reilly et al.,<sup>36</sup> each study rating was qualitatively interpreted using the following law: studies have a risk of bias or low quality with lower punctuation than seven points, while those studies with greater

punctuations are considered as low risk of bias or of high quality. The items were: provide in the abstract an informative and balanced summary of what was done and what was found (item 1); state specific objectives, including any prespecified hypotheses (item 2); Give the eligibility criteria, and the sources and methods of selection of participants (item 3); for each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (item 4); explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (item 5); give characteristics of study participants (item 6); summarize key results with reference to study objectives (item 7); discuss limitations of the study, considering sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (item 8); give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (item 9); give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (item 10).

## **Results**

### *Study identification and selection*

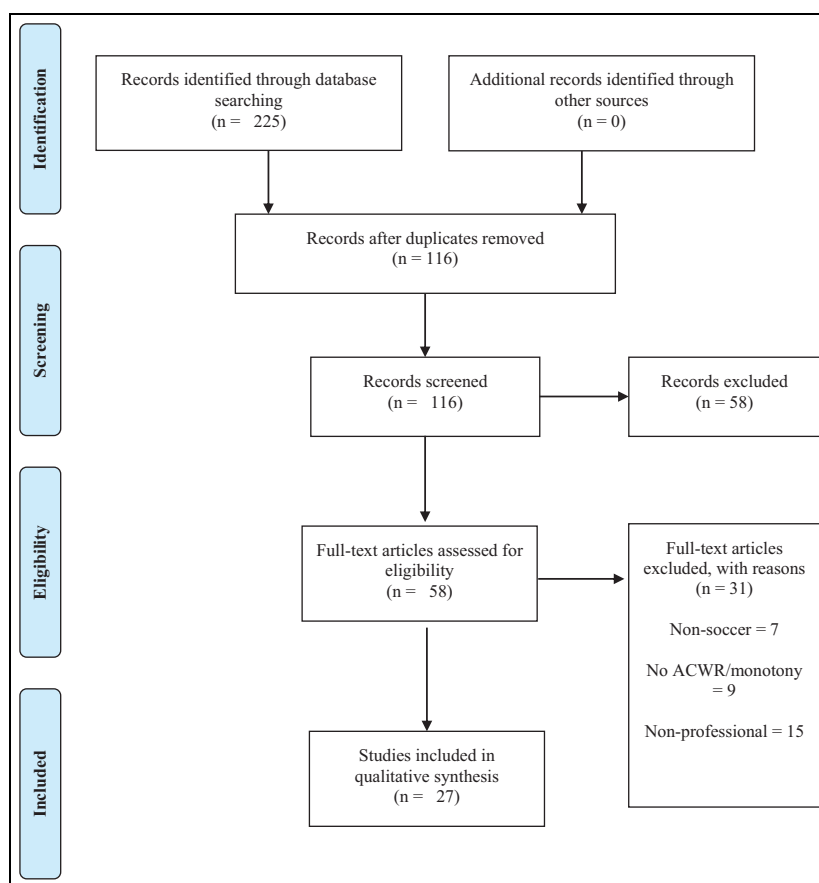
The database search identified a total of 225 titles. These studies were then exported to reference manager software (EndNote™ X9, Clarivate Analytics, Philadelphia, PA, USA). Duplicates (109 references) were subsequently removed either automatically or manually. The remaining 116 articles were screened for their relevance based on titles and abstracts, resulting in the removal of 58 further studies. Following the screening procedure, 58 articles were selected for in depth reading and analysis. After reading full texts, 27 studies were included in the qualitative synthesis (Figure 1).

### *Methodological quality*

The overall methodological quality of the studies can be found in Table 1.

### *Characteristics of individual studies*

The characteristics of the studies that reported acute:chronic workload ratio (ACWR) are detailed in Table 2. From the 27 studies selected, a total of 17 studies analyzed ACWR,<sup>27–29,37,39,42–48,50–52,54,59</sup> in which nine studies used internal load variables,<sup>28,29,39,42–45,50,52</sup> six studies used external load variables<sup>27,37,46,48,51,58</sup> and only two used both internal and external variables<sup>47,54</sup> to calculate ACWR.



**Figure 1.** Flow diagram of the selection of studies.

**Table 1.** Inclusion/exclusion criteria of included studies.

No. of criteria	Inclusion criteria	Exclusion criteria
1	Studies developed with professional soccer players	Studies conducted with non-professional players or in other sports
2	Studies that reported acute/chronic workload ratio and/or monotony	Studies that extracted external TL (not velocity or accelerations) and internal TL. Also, studies not aimed to extract TL.
3	Only original and full-text studies written in English	Written in other 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).

TL: training load.

Apart from the study of Clemente et al.,<sup>58</sup> all studies, analyzed the relationship between ACWR and injuries.<sup>27–29,37,39,42–48,50–52,54</sup>

The characteristics of the studies that reported monotony were detailed in Table 3. From the 27, a total of 10 studies were analyzed in which six studies used internal load variables<sup>2,37,38,41,49,57</sup>, four studies used external load variables<sup>40,53,58,59</sup>; to calculate monotony in which the following formula was used: mean of training load during the 7 days of the week divided by the standard deviation of the training load of the 7 days of the week. Finally, range (minimum and maximum) or mean values were reported for the monotony.

The characteristics of the studies that reported monotony by player positions were detailed in Table 4. Two studies used external load variables to calculate monotony and compare positions of the players.<sup>40,59</sup> Considering the different formulas of ACWR, this table presents an additional column with the respective formulas used.

The characteristics of the studies that reported monotony by player status (starters and non-starters) were detailed in Table 5. Two studies used external load variables to calculate monotony and compare starters versus non-starters (Table 6).<sup>55,56</sup>

Regardless of the number of studies included in this review, the possibilities of comparisons are related to

**Table 2.** Methodological assessment of the included studies.

Reference	1	2	3	4	5	6	7	8	9	10	Quality
Lu et al. <sup>37</sup>		0	0								High
Delecroix et al. <sup>38</sup>		0				0				0	High
Delecroix et al. <sup>39</sup>		0	0			0				0	Low
Enright et al. <sup>27</sup>		0	0			0		0		0	Low
Impellizzeri et al. <sup>29</sup>		0	0								High
Clemente et al. <sup>40</sup>										0	High
Clemente et al. <sup>41</sup>		0								0	High
Noor et al. <sup>42</sup>		0									High
Saidi et al. <sup>2</sup>											High
Malone et al. <sup>43</sup>		0	0							0	High
Lolli et al. <sup>44</sup>	0	0	0	0		0			0		Low
Bowen et al. <sup>45</sup>		0	0								High
Sekiguchi et al. <sup>46</sup>		0	0							0	High
Springham et al. <sup>47</sup>		0	0							0	High
Suarez-Arrones et al. <sup>48</sup>		0	0								High
Morales et al. <sup>49</sup>			0							0	High
McCall et al. <sup>50</sup>		0	0								High
Carey et al. <sup>51</sup>			0			0				0	High
McCall et al. <sup>52</sup>			0							0	High
Houtmeyers et al. <sup>53</sup>		0	0							0	High
Jaspers et al. <sup>54</sup>		0	0							0	High
Fanchini et al. <sup>28</sup>										0	High
Nobari et al. <sup>55</sup>										0	High
Nobari et al. <sup>56</sup>		0								0	High
Fessi et al. <sup>57</sup>		0									High
Clemente et al. <sup>58</sup>		0									High
Clemente et al. <sup>59</sup>		0									High

playing positions (two studies) and status (two studies), while all of the remaining studies are descriptive and comparative, making suitable only the meta-analytical comparison between specific periods or scenarios. In fact, each of the remaining studies are different regarding methodological designs and variables to calculate monotony or ACWR. From this point of view, a meta-analytical comparison was considered unsuitable because it will produce bias and uses a small number of studies.

## Discussion

The aim of this systematic review was to summarize the main evidence regarding the ACWR and training monotony variations over the season in professional soccer players.

### Chronic workload ratio considering the internal load

Taking into account the internal load, mainly s-RPE measures were evaluated to understand the ACWR. As we have commented previously, this research topic is especially targeted toward variations over the season. For this reason, the majority of studies encountered were performed from one,<sup>39,43,44,47,52</sup> two,<sup>54</sup> or three seasons<sup>28,29,45</sup> although some studies were found that were performed during tournaments.<sup>42,50</sup>

The multiplicity of different findings highlights the increase of ACWR throughout the season<sup>42</sup> or links an

increase with very-high-speed actions.<sup>37,54</sup> However, ACWR and its relationship with injuries figure greatly in this research topic. Consequently, we find studies that did not reveal an association with injury risk<sup>29,50,52</sup> and studies that suggest different scale models presumed to be suitable for the ACWR to predict injury risk<sup>44</sup> and lastly, studies that found an association between internal load reflected in s-RPE and ACWR with non-contact injuries, without a relationship with the ability to predict injury.<sup>28</sup> Regarding the previous findings, a stronger association with injury risk was reported by Bowen et al.<sup>45</sup> in the English Premier League and similarly, Delecroix et al.<sup>60</sup> and Malone et al.<sup>43</sup> found injury incidence when the ratio was < 0.85 and when the 2-week ACWR or week-to-week ratio was outside the 0.85–1.25 range or  $\geq 1.00$  to  $\leq 1.25$ , respectively. This variability in the results might be caused by the different protocols of s-RPE implementation (moment, duration, time of assessment with respect to the final session, etc.).<sup>61</sup> Therefore, s-RPE as a variable to control ACWR is not a definitive variable to predict or look for an association with risk of injury.

### Chronic workload ratio considering the external load

Concerning the external load, mainly reflected in GPS results, values were assessed to elucidate the ACWR. In this respect, no association was found between ACWR (session number, session time, player load/min, total

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

Reference	N Sex Age	Duration	Variables	ACWR formula	ACWR (AU)	Concluding remarks
Lu et al. <sup>37</sup>	N: 45 Sex: M Age: 26.4 ± 5.1	2 seasons	Total distance DC < 14.4 km/h DC > 14.5 km/h DC > 20 km/h Mean speed Bodyload s-RPE	Acute load (the week prior to injury week) was divided by the mean of the accumulated 3 weeks prior to injury week	Non-extractable data.	ACWR of all workload metrics markers examined were not excessively inflated, although exposure had a significantly higher ACWR compared to very-high-speed running.
Delecroix et al. <sup>39</sup>	N: 130 Sex: M Age: ND	1 season		1 week load was divided by the total workload of the last 28 days, or last 21 days, or last 14 days	Mean value 0.85–2.11	Injury incidence was higher when the 4 week and 2 week ACWR were < 0.85 or the week-to-week ratio was < 0.85 and when the 2 week ACWR or week-to-week ratio were outside of the 0.85–1.25 range.
Enright et al. <sup>27</sup>	N: 192 Sex: M Age: ND	28 days	Total distance DC > 5.5 m/s DC > 7.0 m/s	Acute load (the week prior to injury week) was divided by chronic workload according to the following: (a) the average of the second and third week prior to the injury (uncoupled ACWR 1:3); (b) the second, third, and fourth week prior to injury (uncoupled ACWR 1:4); (c) the average of the first, second and third week prior to the injury (coupled ACWR 1:3); or (d) the first, second, third, and fourth week prior to injury (coupled ACWR 1:4). The exponentially weighted ACWR known as EWMA was calculated. <sup>25</sup>	Mean values Total distance EWMA = 0.95 ± 0.33–1.03 ± 0.27 1:4 ACWR C = 1.03 ± 0.36–1.06 ± 0.32 1:3 ACWR C = 1.00 ± 0.28–1.07 ± 0.24 1:4 ACWR UC = 0.50 ± 0.25–0.53 ± 0.51 1:3 ACWR UC = 0.86 ± 0.51–0.89 ± 0.42 DC > 5.5 m/s EWMA = 0.95 ± 0.29–1.00 ± 0.39 1:4 ACWR C = 0.99 ± 0.39–1.08 ± 0.30 1:3 ACWR C = 0.99 ± 0.37–1.09 ± 0.23 1:4 ACWR UC = 0.48 ± 0.30–0.57 ± 0.48 1:3 ACWR UC = 0.84 ± 0.46–0.96 ± 0.84 DC > 7.0 m/s EWMA = 0.93 ± 0.42–0.99 ± 0.57 1:4 ACWR C = 1.01 ± 0.61–1.14 ± 0.66 1:3 ACWR C = 0.96 ± 0.51–1.13 ± 0.55 1:4 ACWR UC = 0.58 ± 0.50–0.79 ± 1.08 1:3 ACWR UC = 0.94 ± 0.75–1.26 ± 1.46	There were no observed differences in workload variables and each injury tissue type. In addition, there was no relationship found between workload variables and injury severity.
Impellizzeri et al. <sup>29</sup>	N: 34 Sex: M Age: 26 ± 5	3 seasons	s-RPE	Acute load (the week prior to injury week) was divided by chronic workload of 4, 3, and 2 weeks (preceding the injury)	Mean value 1.010 ± 1.0–1.016 ± 1.017	The etiological theory developed to explain the relation ACWR and injury risk is not supported.
Noor et al. <sup>42</sup>	N: 35 Sex: M Age: 25.9 ± 3.8	3 international tournaments	s-RPE	Acute load was divided by the mean of preceding 3-weeks	Club = 0.77 Camp = 1.41 Tournament = 1.0	An increase in training volume, and ACWR was evident during the transition between club-to-camp periods. Subsequent reductions were observed between the camp-to-tournament periods.

(continued)

**Table 3.** (continued)

Reference	N Sex Age	Duration	Variables	ACWR formula	ACWR (AU)	Concluding remarks
Malone et al. <sup>43</sup>	N: 48 Sex: M Age: 25.3 ± 3.1	1 season	s-RPE	Acute load was divided by chronic workload of 4, 3, and 2 weeks	Lower risk values = 1.00–1.25 Higher risk values ≥ 1.50	A reduced risk of injury in elite soccer players when exposed to ACWR ≥ 1.00–≤ 1.25 was found. It was suggested that different scaling models should be appraised carefully before the ACWR is naturally assumed to be a suitable exposure for injury risk.
Lolli et al. <sup>44</sup>	N:24 Sex: M Age: ND	38 in-season weeks	s-RPE	Acute load was divided by chronic workload (4 weeks)	Non-extractable data.	ACWR had a stronger association to non-contact injury risk in this cohort of English Premier League football players than accumulated loads, suggesting the rapid increase in load is more indicative of injury than the cumulative amount of load performed. For English Premier League football players, when chronic load exposure is low, an ACWR > 2 is associated with 5–7 times the risk of a soft tissue injury than players whose ACWR is below to that number.
Bowen et al. <sup>45</sup>	N: 33 Sex: M Age: 25.4 ± 3.1	3 seasons	s-RPE	Acute load was divided by chronic workload (4 weeks)	Non-extractable data.	ACWR of session time, player load and total distance were similar. Only higher ACWR of session time was significantly associated with lower heart rate variability.
Sekiguchi et al. <sup>46</sup>	N: 23 Sex: M Age: 21 ± 1	14 weeks	Session time Player load Player load/min Total distance	Acute load was divided by chronic workload (4 weeks)	Mean values 0.5 ± 0.2–3.0 ± 1.0 0.5 ± 0.3–3.0 ± 1.2 0.5 ± 0.2–2.4 ± 1.6 0.4 ± 0.4–2.9 ± 1.1	To determine match play HMLD performance potential, the results suggested the use of uncoupled (acute, chronic) as opposed to coupled ACWR.
Springham et al. <sup>47</sup>	N: 18 Sex: M Age: 24 ± 4	1 season	HMLD RPE DC > 5.5 m/s Sprint Acceleration Deceleration	EWMA <sup>25</sup>	Non-extractable data.	The present study demonstrated that spikes in the ACWR were not related to a subsequent injury occurrence in professional soccer players.
Suarez-Arrones et al. <sup>48</sup>	N: 15 Sex: M Age: 18.6 ± 0.8	10 weeks	Total distance DC > 14.4 km/h DC > 18.0 km/h DC > 21.0 km/h DC > 24 km/h	Acute load was divided by chronic workload (4 weeks, acute load was not included)	Mean values 1.00 ± 0.31–1.45 ± 1.91 0.97 ± 0.30–1.86 ± 2.76 0.94 ± 0.30–2.47 ± 3.15 0.92 ± 0.57–3.39 ± 6.15 0.87 ± 0.41–2.19 ± 2.59	

(continued)

Table 3. (continued)

Reference	N Sex Age	Duration	Variables	ACWR formula	ACWR (AU)	Concluding remarks
McCall et al. <sup>50</sup>	N: 17 (Brazil) Sex: M 26.6 ± 4.7 N: 16 (Asian) Sex: M Age: 26.1 ± 3.5 N: 23,742 Soccer Sex: ND Age: ND	2 tournaments	s-RPE Sessions number	Acute load was divided by chronic workload (4 weeks)	Injured = 1.0–1.7 ± 0.5 Not-injured = 0.9 ± 0.2–1.3 ± 0.7 Injured = 1.5 ± 0.5 Not-injured = 1.0 ± 0.1–1.2 ± 0.2	ACWR did not conclusively define injured and non-injured players.
Carey et al. <sup>51</sup>	N: 171 Sex: M Age: 25.1 ± 4.9	2 seasons	Total distance	Acute load was divided by chronic workload (4 weeks)	Mean value 1.05 ± 0.42	Modeling methods that discretize continuous risk factors are inappropriate for studying the relationship between training loads and injuries.
McCall et al. <sup>52</sup>	N: 171 Sex: M Age: 25.1 ± 4.9	1 season	s-RPE	Acute load was divided by chronic workload of 4, 3, and 2 weeks	Higher injury risk 4-weeks = > 0.97 3-weeks = > 1.42 2-weeks = Non-extractable data.	This study provides evidence for the ACWR as a risk factor for non-contact injury in elite European players. However, in isolation, ACWR should not be used to predict non-contact injury.
Jaspers et al. <sup>54</sup>	N: 35 Sex: M Age: 23.2 ± 3.7	2 seasons	Total distance DC > 20 km/h Acc number (> 1 m/s <sup>2</sup> ) Dec number (< -1 m/s <sup>2</sup> )	Acute load was divided by chronic workload (4 weeks)	Non-extractable data Harmful effect > 1.18 Beneficial effect 0.87–1.12 Beneficial effect 0.86–1.12 Beneficial effect > 0.85	A high ACWR for DC > 20 km.h <sup>-1</sup> should be avoided, while protective effects were found and a medium ACWR is recommended for Acc, Dec and s-RPE (-0.85–1.12).
Fanchini et al. <sup>28</sup>	N: 34 Sex: M Age: 26 ± 5	3 seasons	s-RPE	Acute load was divided by chronic workload (4 weeks)	Higher injury risk 4-weeks = > 0.97 3-weeks = > 1.01 2-weeks = > 0.78	Association between s-RPE derived training and relative measures of ACWR for 2, 3, and 4 weeks were found with non-contact injury. However, this should not be confused with ability to predict injury at an individual player level.
Clemente et al. <sup>58</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season	HMLD Acc Dec	Acute load was divided by chronic workload (4 weeks)	Mean values S1M = 1.0 ± 0.5 S2M = 1.0 ± 0.3 S3M = 1.0 ± 0.3 S1M = 1.1 ± 0.5 S2M = 1.0 ± 0.2 S3M = 1.0 ± 0.3 S1M = 1.0 ± 0.5 S2M = 1.0 ± 0.2 S3M = 1.0 ± 0.3	No significant ACWR changes were found.

ND: non-described; M: male; F: female; DC: distance covered; S1M: starter in one match; S2M: starter in two matches; S3M: starter in three matches; Acc: acceleration; Dec: deceleration; HMLD: high metabolic load distance; RPE: rated perceived exertion; s-RPE: session rated perceived exertion.

**Table 4.** Characteristics, summary, and evidence about monotony studies.

Reference	N Sex Age	Duration	Variables	Monotony (AU)	Concluding remarks
Lu et al. <sup>37</sup>	N: 45 Sex: M Age: 26.4 ± 5.1	2 seasons	s-RPE	1.6–2	Monotony was not significantly different across all weeks.
Delecroix et al. <sup>38</sup>	N: 130 Sex: M Age: 26.3 ± 4.9	1 season	s-RPE	Non-extractable data.	There was no link between the weekly monotony and the injury incidence except for the 4-weeks monotony that was related to the injury incidence. The regression analysis indicated that there was a decrease in the injury incidence with an increase of the 4-weeks monotony.
Clemente et al. <sup>40</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season (pre and in-season)	HMLD Impacts Acc Dec HMLD Impacts Acc Dec	0.7–5.7 0.6–3.8 0.7–5.2 0.7–5.2 Pre-season = 2.0 ± 1.2 First half = 1.5 ± 1.1 Second half = 1.5 ± 1.0 Pre-season = 1.8 ± 1.0 First half = 1.2 ± 0.9 Second half = 1.2 ± 0.8 Pre-season = 1.7 ± 0.8 First half = 1.6 ± 0.9 Second half = 1.7 ± 1.0 Pre-season = 1.7 ± 0.8 First half = 1.6 ± 1.1 Second half = 1.7 ± 0.9	Greater training monotony was found in the pre-season than in the first and second halves of the season, but no significant differences were found for any other measures.
Clemente et al. <sup>41</sup>	N: 27 Sex: M Age: 24.9 ± 3.5	10 weeks	s-RPE	0.9–3.8	Monotony decreased as the weeks progressed through the season.
Saidi et al. <sup>2</sup>	N: 16 Sex: M Age: 19–22	12 weeks	s-RPE	Non-congested = 0.49 ± 0.07 Congested = 1.87 ± 0.16	Higher values of monotony were revealed in congested period.
Morales et al. <sup>49</sup>	N: 16 Sex: F Age: 23.3 ± 5.1	6 weeks	s-RPE	~1.25–1.35	It was observed that training sessions were not properly managed, because a significant reduction in TLs should result in a corresponding reduction in monotony, which was not the case in the last 3 weeks.

(continued)

Table 4. (continued)

Reference	N Sex Age	Duration	Variables	Monotony (AU)	Concluding remarks
Houtmeyers et al. <sup>53</sup>	N: 11 Sex: M Age: 25.1 ± 2.8	33 weeks	Total distance DC 12–15 km/h DC 15–20 km/h DC 20–25 km/h DC > 25 km/h Total distance DC 12–15 km/h DC 15–20 km/h DC 20–25 km/h DC > 25 km/h	Non-congested 1.30 ± 0.06 1.10 ± 0.15 1.07 ± 0.14 0.93 ± 0.09 0.64 ± 0.11 Congested 1.10 ± 0.05 0.86 ± 0.07 0.85 ± 0.08 0.77 ± 0.07 0.68 ± 0.10 Pre-season = 1.8 ± 0.1 In-season = 1.1 ± 0.1	Monotony calculated through DC variables showed to be lower during congested weeks when compared to non-congested weeks.
Fessi et al. <sup>57</sup>	N: 17 Sex: M Age: 23.7 ± 3.2	1 week (pre-season) 1 week (in-season)	s-RPE	Pre-season = 1.8 ± 0.1 In-season = 1.1 ± 0.1	Higher monotony in pre-season than in-season.
Clemente et al. <sup>58</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season	HMLD Acc Dec	S1M = 0.8 ± 0.2 S2M = 0.8 ± 0.3 S3M = 0.7 ± 0.1 S1M = 1.0 ± 0.4 S2M = 1.2 ± 0.4 S3M = 0.9 ± 0.2 S1M = 0.9 ± 0.3 S2M = 1.0 ± 0.3 S3M = 0.8 ± 0.2	Accelerometry-based measures were dependent on congested fixtures. S2M had the greatest Strain values, while S3M had the greatest monotony values.
Clemente et al. <sup>59</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season (pre and in-season)	Total distance DC ≥ 19.8 km/h DC ≥ 14 km/h Sprints number ≥ 25.2 km/h	Pre-season = 2.3 ± 1.0 First half = 2.0 ± 1.1 Second half = 2.0 ± 1.1 Pre-season = 1.3 ± 0.7 First half = 0.0 ± 0.4 Second half = 0.9 ± 0.5 Pre-season = 1.9 ± 1.6 First half = 1.2 ± 1.2 Second half = 1.2 ± 0.8 Pre-season = 0.9 ± 0.4 First half = 0.6 ± 0.3 Second half = 0.6 ± 0.3	Greater acute load, training monotony, and training strain occurred in the pre-season and progressively decreased across the season.

ND: non-described; M: male; F: female; DC: distance covered; S1M: starter in one match; S2M: starter in two matches; S3M: starter in three matches; Acc: acceleration; Dec: deceleration; HMLD: high metabolic load distance; RPE: rated perceived exertion; s-RPE: session rated perceived exertion.

**Table 5.** Characteristics, summary, and evidence about monotony by player positions.

Ref.	N Sex Age	Duration	Variables	Wide defenders	Central defenders	Midfielders	Wide Midfielders	Strikers	Concluding remarks
Clemente et al. <sup>40</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season (pre and in-season)	HMLD	WD = 1.5 ± 0.9	CD = 1.6 ± 1.3	MF = 1.5	WM = 1.5 ± 1.1	ST = 1.4 ± 0.6	Central defenders exhibited the lowest values of HMLD, while wide defenders and midfielders presented the greatest impacts over the season.
Clemente et al. <sup>59</sup>	N: 19 Sex: M Age: 26.5 ± 4.3	1 season (pre and in-season)	Impacts	WD = 1.3 ± 0.9	CD = 1.3 ± 0.8	MF = 1.3 ± 1.1	WM = 1.2 ± 1.0	ST = 1.1 ± 0.7	Results revealed moderate effect size differences for the number of sprints in acute load, training monotony and training strain.
			Acc	WD = 1.8 ± 1.0	CD = 1.8 ± 0.9	MF = 1.7 ± 0.9	WM = 1.8 ± 1.0	ST = 1.8	
			Dec	WD = 1.6 ± 1.0	CD = 1.6 ± 0.8	MF = 1.6 ± 1.3	WM = 1.7 ± 1.0	ST = 1.7 ± 0.7	
			Total distance	WD = 1.0 ± 0.5	CD = 0.9 ± 0.4	MF = 0.9 ± 0.5	WM = 1.0 ± 0.6	ST = 0.9 ± 0.5	
			DC ≥ 19.8 km/h	WD = 1.0 ± 0.5	CD = 0.9 ± 0.4	MF = 0.9 ± 0.5	WM = 1.0 ± 0.6	ST = 0.9 ± 0.5	
			DC ≥ 14 km/h	DC ≥ 14 km/h	CD = 1.2 ± 0.6	MF = 1.2 ± 0.7	WM = 1.2 ± 0.7	ST = 1.3 ± 1.5	
			Sprints number ≥ 25.2 km/h	WD = 1.5 ± 1.9	CD = 0.6 ± 0.3	MF = 0.5 ± 0.2	WM = 0.7 ± 0.3	ST = 0.6 ± 0.2	

M: male; DC: distance covered; Acc: acceleration; Dec: deceleration; HMLD: high metabolic load distance.

**Table 6.** Characteristics, summary, and evidence about monotony by player status.

Reference	N Sex Age	Duration	Variables	Starters	Non-starters	Concluding remarks
Nobari et al. <sup>56</sup>	N: 21 Sex: M Age: 28.3 ± 3.8	1 season (pre and in-season)	Acc (< 2 m/s <sup>2</sup> )	Pre-season = 3.25 ± 0.62	Pre-season = 1.19 ± 0.39	Monotony values were higher for starters compared to non-starters through the full-season, which confirms that the training session does not provide a sufficient load to non-starter soccer players during the full-season.
				Early-season = 1.87 ± 0.36	Early-season = 1.09 ± 0.12	
				Mid-season = 2.12 ± 0.37	Mid-season = 1.11 ± 0.27	
				End-season = 2.48 ± 0.79	End-season = 0.93 ± 0.10	
				Pre-season = 1.82 ± 0.26	Pre-season = 1.19 ± 0.39	
				Early-season = 1.76 ± 0.36	Early-season = 1.09 ± 0.12	
				Mid-season = 1.87 ± 0.27	Mid-season = 1.11 ± 0.27	
				End-season = 2.10 ± 0.55	End-season = 0.93 ± 0.10	
				Pre-season = 0.94 ± 0.10	Pre-season = 0.70 ± 0.13	
				Early-season = 0.95 ± 0.14	Early-season = 0.80 ± 0.11	
				Mid-season = 0.98 ± 0.09	Mid-season = 0.78 ± 0.18	
				End-season = 1.05 ± 0.14	End-season = 0.70 ± 0.09	
				Pre-season = 1.82 ± 0.19	Pre-season = 1.31 ± 0.44	
Nobari et al. <sup>55</sup>	N:21 Sex: M Age: 28.3 ± 3.8	1 season (pre and in-season)	Dec (< -2 m/s <sup>2</sup> )	Early-season = 1.80 ± 0.33	Early-season = 1.09 ± 0.16	Starters regularly present higher values monotony for body load and metabolic power than non-starters.
				Mid-season = 1.98 ± 0.27	Mid-season = 1.06 ± 0.22	
				End-season = 2.33 ± 0.67	End-season = 0.94 ± 0.12	
				Pre-season = 1.56 ± 0.19	Pre-season = 1.07 ± 0.32	
				Early-season = 1.56 ± 0.26	Early-season = 0.97 ± 0.11	
				Mid-season = 1.65 ± 0.24	Mid-season = 1.01 ± 0.17	
				End-season = 1.79 ± 0.33	End-season = 0.88 ± 0.12	
				Pre-season = 1.03 ± 0.11	Pre-season = 0.80 ± 0.18	
				Early-season = 1.08 ± 0.09	Early-season = 0.81 ± 0.12	
				Mid-season = 1.14 ± 0.19	Mid-season = 0.78 ± 0.11	
				End-season = 1.11 ± 0.16	End-season = 0.74 ± 0.07	
				Pre-season = 2.69 ± 0.52	Pre-season = 1.57 ± 0.62	
				Early-season = 2.18 ± 0.49	Early-season = 1.26 ± 0.20	
Mid-season = 2.32 ± 0.46	Mid-season = 1.22 ± 0.25					
End-season = 2.20 ± 0.58	End-season = 0.98 ± 0.12					
Pre-season = 2.97 ± 0.41	Pre-season = 1.72 ± 0.70					
Early-season = 2.70 ± 0.56	Early-season = 1.52 ± 0.18					
Mid-season = 2.84 ± 0.46	Mid-season = 1.34 ± 0.42					
End-season = 2.26 ± 0.51	End-season = 1.05 ± 0.15					

distance, high metabolic load distance (HMLD), sprint, acceleration number, deceleration number, DC to different running speeds, and HMLD) and injury risk.<sup>27,37,46–48,50,51,58</sup> However, the literature crucially revealed that a higher ACWR is related to very-high-speed running,<sup>37,54</sup> that a higher ACWR is linked to lower heart rate variability<sup>46</sup> and the conclusion that to neglect continuous risk factors is inappropriate for studying the relationship between training loads and injuries.<sup>51</sup> In all cases, professional soccer staff should know about the specific nature of the sport and excessive distance covered (DC) >20 km/h should be avoided. This finding suggests that control of ACWR using Accelerations and Decelerations (~0.85–1.12) might be protective against injuries.<sup>54</sup>

In short, as more information becomes available regarding the integration of external and internal load, staff might have more control over professional soccer players' loads and their relevancy in game development and the reduction of injuries. For this reason, according to the new findings, more research will be necessary to clarify the mechanism that explains the internal and external load in ACWR.

### *Monotony considering the internal load*

As in the case of ACWR, training monotony was explored regarding the variations across the season. Crucially, results achieved over time reflect diverse findings and have generated controversy. As seen above, in the case of the study by Noor et al.<sup>42</sup> that showed that an increment in training volume and ACWR (s-RPE) was evident during the transition between club-to-camp periods and after, reductions were observed between the camp-to-tournament periods. In fact, this training monotony, shown in s-RPE, was higher in the preseason than in season<sup>57</sup> which might explain the different levels of physical condition and the adaptation period found in the preseason.

Regarding the s-RPE variable, it should be mentioned that in one study<sup>37</sup> which was performed during two seasons, the authors showed that the s-RPE was not significantly different across all weeks. However in other studies performed during 10 weeks and 1 season, respectively, Clemente et al.<sup>41</sup> revealed that training monotony decreased as the weeks progressed through the season, similar to the results encountered by Morales et al.,<sup>49</sup> in a study conducted during 6 weeks which found a reduction of the monotony in the last 3 weeks. In addition, Saidi et al.<sup>2</sup> revealed in a study performed during 12 weeks that higher values of monotony were recorded in the highly scheduled competition periods. Last, Delecroix et al.<sup>38</sup> showed by a regression analysis a decrease in the injury incidence with an increase in the 4-week monotony, results that could suggest controlling training and individual differences.

### *Monotony considering the external load*

When addressing the monotony of external load factors (HMLD, impacts, accelerations, decelerations, total distance, DC at different intensities, and sprint numbers) diverse findings complement the results seen in ACWR studies. For example Houtmeyers et al.<sup>53</sup> investigated, through DC variables, calculated training monotony and found lower values during highly scheduled competition weeks when compared to low competition weeks. This research fits with the study by Clemente et al.,<sup>58</sup> that found similar evidence using HMLD, accelerations, deceleration, and accelerometry. In fact, this study suggests that greater training monotony was found in the pre-season reflected in HMLD, impacts, accelerations, and decelerations.<sup>40</sup> At this point, training monotony by players' positions had to be investigated and assessed. Accordingly, in the study by Clemente et al.<sup>40</sup> lower values of HMLD were observed in central defenders, and the wide defenders and midfielders presented the greatest impacts over the season. This finding is reinforced by the study by Nobari et al.<sup>56</sup> that revealed a higher monotony value (body load and metabolic power) for starters compared to non-starter soccer players through the full season.

To summarize, the literature suggests that individual load control is a key factor to examining training monotony in detail. Therefore, we could suggest the assessment of training monotony by player positions, functions in the field or participation time, which could help avoid discomfort and injury.

Several limitations exist in this review. The wide variety of results characterized by different: (i) study designs, (ii) methods used, (iii) ACWR and monotony ranges, (iv) variables assessed, (v) durations of the studies, and (vi) approaches and findings, among others, revealed that more research is needed. Additionally, most of the studies performed are potentially limited because the aforementioned ratios were analyzed in a single team during all seasons with different competitions. Nevertheless, it should be noted that the findings are relevant partly due to the sample of professional soccer players and the concrete difficulty in gaining access to them. In addition, it is necessary to make reference to the methodological quality of the manuscripts. As had been noted, except for two studies<sup>27,39</sup> the remaining studies<sup>2,20,21,29,30,32–51</sup> were of high quality. For this reason, the scientific community should interpret the results with caution to avoid bias, mainly caused by the study designs and methods used, a factor which could further help in the development of new research about ACWR and training monotony variations.

Regarding the methodological quality of different studies included in this systematic review, at least two studies selected<sup>27,39</sup> were of low methodological quality. In this respect, the weaknesses of the methodology were

that neither study included prespecified hypotheses, or eligibility criteria for the selection of participants. Indeed, the studies did not include sources of data and details of methods of assessment or funding and the role of the funders. Moreover, one study<sup>27</sup> did not show the direction and magnitude of any potential bias. The other 25 studies revealed a high methodological quality characterized by well-established research designs, a rigorous sampling strategy, or the use of reliable and valid measures. Therefore, the present work was conducted in a rigorous and systematic way to avoid the authors' interpretation affecting the study results and indicates the extent to which the findings can be generalized to this specific population.

### Practical implications and future research

The outcome of the present systematic review highlights the reference values of ACWR and training monotony in professional soccer and goes deeper into the variations of load measures (internal and external) across the season. In fact, the results suggest that ACWR and training monotony play a key role in soccer science due to their relationship with other training factors.

To provide a wide understanding about ACWR and training monotony and improve the controlling and monitoring of load by professional soccer staff, a comprehensive model could be strengthened regarding knowledge about injury risk. For this reason, the following specific recommendations may be helpful:

- *Create intelligent and independent soccer players:* Professional soccer players should be familiarized with external and internal loads to assume responsibility for their training and improve their load perception.
- *Build multidisciplinary teams:* Multidisciplinary teams facilitate goal achievement. Coaches, physical trainers, the medical team, physiotherapists and sports data scientists, among others, may provide their individual contributions, while their expertise further strengthens the collective.
- *Create individual indices or reference marks that should not be exceeded:* Given the multifactorial aspect of performance, professional soccer staff must build factors that avoid a high risk of suffering an injury or illness.
- *Promote efficient and intelligent models:* The creation of intelligent models in professional soccer capable of considering a large amount of ACWR and training monotony measures both at the external and internal load level for inform team staff about predictions.

The analysis and prediction of ACWR and training monotony performance have been the subject of much research due to their complexity and importance in professional soccer. For this reason, new research should be carried out considering the different changes

produced through the weeks of the season. Therefore, monitoring and controlling the kind of training and workload (internal and external), and the statistical methods applied could be a key factor for improving knowledge on this topic. Future studies may further the understanding of new intelligent models based on artificial intelligence and create tools that connect values of ACWR and training monotony training, to monitor and evaluate the impact of acute and chronic training.

### Conclusions

This systematic review intended to summarize the typical values of ACWR and training monotony in professional soccer, considering different load measures (internal and external), revealing significant interest among sport science experts in soccer. In fact, a large quantity of studies of very good quality and long duration (one to three seasons) were encountered. However, among the wide variety of results characterized by different (i) designs, (ii) ACWR and monotony ranges, (iii) variables assessed, and (iv) durations of the studies, the literature reveals that ACWR and training monotony (internal and external) may relate to injury risk when both loads were explored in the same study. Notwithstanding, it is not clear when only one type of load was explored. In all cases regarding ACWR the ratios located around 0.85–1.25 could predict lower risk values and ratios around  $\geq 1.50$  could predict higher risk. Nevertheless, the data did not conclusively define injured and non-injured players. In respect of training monotony, the ratios are approximately between 0.5 and 2.00 (low values in the preseason and low competition weeks and high values when soccer players experience highly scheduled competition weeks).

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Rafael Oliveira is also affiliated to Research Centre in Sport Sciences, Health Sciences and Human Development, Vila Real, Portugal.

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### ORCID iDs

Markel Rico-González  <https://orcid.org/0000-0002-9849-0444>

Francisco Tomás González Fernández  <https://orcid.org/0000-0002-1480-7521>

Rafael Oliveira  <https://orcid.org/0000-0001-6671-6229>

Filipe Manuel Clemente  <https://orcid.org/0000-0001-9813-2842>

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