JOMH
Journal of Men's Health

J. Mens. Health **2022**; 18(4): 94
https://doi.org/10.31083/j.jomh1804094

Original Research

Within- and between-mesocycle variations of well-being measures in top elite male soccer players: a longitudinal study

Rafael Oliveira[1,2,3,*], Halil İbrahim Ceylan[4], João Paulo Brito[1,2,3], Alexandre Martins[1,2,5], Matilde Nalha[1], Bruno Mendes[6], Filipe Manuel Clemente[7,8]

[1]Sports Science School of Rio Maior–Polytechnic Institute of Santarém, 2040-413 Rio Maior, Portugal
[2]Life Quality Research Centre, 2040-413 Rio Maior, Portugal
[3]Research Center in Sport Sciences, Health Sciences and Human Development, 5001-801 Vila Real, Portugal
[4]Ataturk University, Faculty of Kazim Karabekir Education, Physical Education and Sports Teaching Department, 25240 Erzurum, Turkey
[5]Comprehensive Health Research Centre (CHRC), Departamento de Desporto e Saúde, Escola de Saúde e Desenvolvimento Humano, Universidade de Évora, Largo dos Colegiais, 7000 Évora, Portugal
[6]Faculty of Human Kinetics, University of Lisbon, 1649-004 Lisbon, Portugal
[7]Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, 4900-347 Viana do Castelo, Portugal
[8]Instituto de Telecomunicações, Delegação da Covilhã, 1049-001 Lisboa, Portugal
*Correspondence: rafaeloliveira@esdrm.ipsantarem.pt (Rafael Oliveira)
Submitted: 14 December 2021 Revised: 21 December 2021 Accepted: 17 January 2022 Published: 7 April 2022

Abstract

Background: The aims of this study were to describe the variations of training monotony (TM), training strain (TS), and acute:chronic workload ratio (ACWR) through Hooper Index categories (fatigue, stress, DOMS, and sleep quality) and to compare those variations between player status and player positions. **Methods**: Seventeen male professional soccer players participated in this study. Considering player status, participants were divided in nine starters and eight non-starters. Additionally, participants were divided by playing positions: three wide defenders, four central defenders, three wide midfielders, four central midfielders, and three strikers. They were followed during 40-week in-season period. TM, TS, and ACWR were calculated for each HI category, respectively. Data were grouped in 10 mesocycles for further analysis. **Results**: Results showed variations across the mesocycles. In general, starters showed higher values for TM, TS, and ACWR calculations than non-starters, although there were some exceptions. Regarding player positions, significant differences were found in stress between wide defenders vs central midfielders for TM (p = 0.033, ES = 5.16), central defenders vs wide defenders for ACWR (p = 0.044, ES = 4.95), and in sleep between wide defenders and strikers for TM (p = 0.015, ES = 5.80). **Conclusions**: This study revealed that an analysis of players' well-being parameters according to player status and positions can provide clear information to the coaches and their staff to complement the tasks of training monitoring.

Keywords: ACWR; fatigue; football; muscle soreness; training monotony; training strain; sleep; stress

1. Introduction

Monitoring intensity, well-being, and readiness in soccer players have become an essential strategy to acknowledge the magnitude of exercise and to individualize the training process [1]. Since in professional soccer, the players are exposed to regular congested periods, monitoring the variation of training intensity and the fluctuations of well-being can be determinant to ensure the most appropriate recovery processes, favoring the readiness of players for the determinant moments of competition [2,3]. The monitoring process is commonly used to classify the standardized intensity of exercise in the player. Recently, Staunton *et al*. [4] recommend using the term "intensity" instead of "training load" or "load" according to the "International System of Units" which was followed by the present study with the exception for some definitions that will be explained in the following paragraphs (e.g., monotony, strain and acute: chronic workload ratio). Monitoring training intensity allows to quantifying locomotor, mechanical, or physiological measures and providing information about how these measures impact the players [5]. Examples of training intensity variables are heart rate or the session rate of perceived exertion (s-RPE, as internal dimension) and distances covered at different speed intensities or accelerations and decelerations (as external intensity) [6,7]. Moreover, the session-RPE (s-RPE) is accepted as a valuable global indicator of internal training intensity in team sports [8,9] and it had shown to be reliable in soccer [10]. Monitoring these measures allows coaches to identify the physical and physiological effects of training drills and sessions and may allow them to standardize the training stimulus based on the individual responses to the exercise [11].

Training intensity and its overall impact on the player may conduct to variations in the well-being [1]. Well-being is a wide concept, although in the case of sports is commonly centered in the main outcomes of sleep quality, delayed onset muscle soreness (DOMS), fatigue, stress, or mood [12]. Those measures are typically analysed in a subjective way and are not exclusively dependent on the interaction with training intensity [13]. However, they may help coaches to individualize recovery strategies or also help to plan some lifestyle changes to improve the overall response. A tool used to control well-being is the Hooper Index (HI) questionnaire [14]. It has become popular among the professional teams. This questionnaire inquires the players about the perceptive status of four categories: sleep quality, stress, fatigue, and DOMS.

Monitoring intensity and well-being is part of daily strategies used with players to control their variations within- and between weeks [15,16]. However, additional analyses can be performed to specific data obtained. As an example, the training monotony (TM, mean of the week training load/standard deviation of the mean of the week training load), and training strain (TS, accumulated load of the week x monotony) were developed by Foster [9] to provide a visualization of the variability of the week intensity (TM) and the strain promoted in the players (relationships between variability and the acute intensity imposed in the week). Later, the acute:chronic workload ratio (ACWR) was proposed to provide an idea of between-week variation in training intensity imposed, namely comparing the intensity imposed in a week with the previous four weeks [17].

The above-mentioned indexes were developed to understand the variations of training intensity within and between weeks [18–21]. However, such an approach in well-being parameters was never established, as far as we may know. Although studies report weekly well-being variations [22,23], the analysis is always focused on the percentage of change and not in the within-week variation or relationship with the past weeks. Testing the concepts of TM, TS, and ACWR as a calculation approach can add more information about the variation of the well-being of players within and between weeks. A study conducted by Nobari *et al*. [24] did not use these measures, but it considered the between week variations and revealed meaningful changes of well-being measures across pre-season, early-season, mid-season, and end-season. Specifically, the study found higher values of weekly DOMS, fatigue and stress in end-season that early of mid-season. In another study different phases of the season were compared and, it was observed that pre-season conducted to higher stress and fatigue in comparison to in-season [25].

Variations between and within-week can be influenced by different factors. As an example, previous studies reported that the level of participation in matches (starters vs. non-starters) had an impact on the index calculations in professional soccer players [26,27]. Additionally, the impact of intensity can be also determined by the playing position and the role in matches [19]. For instance, Clemente *et al*. [28] suggested that well-being can be also moderated by those factors (level of participation in matches and playing positions) and recommended more studies to analyze internal intensity and the relationship with HI, considering the differences between player positions. Such analysis could help prescribers to be attentive to the impact of these factors on the well-being and eventually adjust strategies based on the player's needs. Therefore, the main goals of the present study were: (a) to describe and compare the in-season variations of TM, TS, and ACWR through fatigue, stress, DOMS, and sleep quality of professional male soccer players; (b) to compare those variations between player positions and status (starters and non-starters).

2. Materials and methods

2.1 Participants

Seventeen male participants that belonged to a team that participated in UEFA Champions League took part in this study. Participants were divided according to playing status: nine starters (age 26.2 $\pm$ 3.5 years, 78.7 $\pm$ 5.8 kg and 180.1 $\pm$ 6.8 cm) and eight non-starters (24.5 $\pm$ 4.6 years, 76.6 $\pm$ 4.3 kg and 182 $\pm$ 6.8 cm). Additionally, and to address the comparisons between playing positions, they were divided in: three wide defenders (WD), four central defenders (CD), three wide midfielders (WM), four central midfielders (CM), and three strikers (ST) according to previous studies [19,20,29,30]. The inclusion/exclusion criteria was adapted from previous studies which follow a participation $\geq$80% of weekly training sessions to be included in the study, while the exclusion criteria include illness, and/or injury for $\geq$2 consecutive weeks [20,21,23,31]. Goalkeepers were removed from analysis because of the differences in terms of physical activity provided by this position in training or competition when compared to the others [27,29].

To define playing status (starters and non-starters), players were assessed on a weekly basis regarding the attendance time at the match. To be considered a starter, a participation $\geq$60 minutes in three consecutive matches was needed while players who did not achieve that minimum were considered non-starters [21,27,32,33].

2.2 Design

The data was collected during the 2015–2016 in-season which included 40-weeks. The team used for analysis participated in four competitions that included the national league, two national cups and the UEFA Champions League. Only main training sessions were considered for analysis which means that rehabilitation or additional recovery training sessions were excluded due to the differences in the intensity of such session and to keep the data comparable through the entire season.

The period analysed included ten months/mesocycles (M, M1 to 10) according to previous studies [20,21,31]. Table 1 shows the number of training sessions, number of official matches, total amount of training duration and s-RPE for the whole team, plus the non-traumatic injuries occurrence per playing status and playing position.

Table 1. Characteristics of mesocycles considering training sessions, competitive matches, s-RPE and injuries during the 10 mesocycles.

Mesocycle (M)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Number of training sessions (n)	16	20	18	18	20	20	19	20	18	20
Number of matches (n)	4	5	4	5	6	8	5	4	7	4
Accumulated training duration (min)	1543	1805	1007	1460	1130	1068	1505	1480	1282	1543
s-RPE for overall team (AU)	328.9	285.9	296.5	259.5	210.8	259.3	248.2	245.3	247.4	242.3
Non-traumatic injuries for starters (n)	4	2	3	3	0	4	2	3	2	0
Non-traumatic injuries for non-starters (n)	0	0	3	2	0	0	4	0	2	0
Non-traumatic injuries for CD (n)	3	0	0	0	0	4	0	0	0	0
Non-traumatic injuries for WD (n)	0	0	0	2	0	0	0	0	0	0
Non-traumatic injuries for CM (n)	0	0	0	3	0	4	0	3	0	0
Non-traumatic injuries for WM (n)	0	2	0	0	0	0	2	3	2	0
Non-traumatic injuries for ST (n)	4	0	3	0	0	0	0	0	2	0

s-RPE, session rated of perceived exertion; AU, arbitrary units; CD, central defenders; WD, wide defenders; CM, central midfielders; WM, wide midfielders; ST, strikers.

2.3 Quantification of session-rated of perceived exertion

The CR10-point scale, adapted by Foster *et al.* [34] was applied thirty minutes after the end of each training session/match through an app on a tablet. All players rated their RPE which were then multiplied by the session durations to obtain the s-RPE [34,35]. The players were previously familiarized with the scale, and all answers were provided individually to avoid non-valid scores.

2.4 Well-being quantification

Approximately 30 minutes before each training session, each player was asked to provide the Hooper Index (HI) scores that include four categories: fatigue, stress, muscle soreness and quality of sleep [14] using a google forms questionnaire app on a tablet. The categories of fatigue, stress, muscle soreness were measured on a 1–7 scale (1 is very, very low and 7 is very, very high), while sleep quality of the previous night was measured on a 1–7 scale (1 is very, very good and 7 is very, very bad). All categories were measured in Arbitrary Units (AU).

Before the study, all participants were familiarized with HI. To avoid non-valid scores, all players individually answered to the different categories.

Finally, the following indexes were calculated with the four categories of HI:

(i) TM – training monotony [16,19,32]

$$TM = \frac{\text{mean of training load during the seven days of the week}}{\text{standard deviation of training load during the seven days of the week}}$$

(ii) TS – training strain [16,19,32]

$$TS = \text{sum of the training loads for all training sessions during a week} \times \text{TM}$$

(iii) ACWR – acute:chronic workload ratio [36–38]

$$ACWR = \frac{\text{acute workload (most recent week)}}{\text{chronic workload (last 4 weeks)}}$$

Through the previous calculations, the following measures were used for analysis:

-TM fatigue, TM stress, TM DOMS, TM sleep;

-TS fatigue, TS stress, TS DOMS, TS sleep;

-ACWR fatigue, ACWR stress, ACWR DOMS, ACWR sleep.

2.5 Statistical analysis

All data was analysed through SPSS version 22.0 (SPSS Inc., Chicago, IL, USA) for Windows statistical software package. Initially, the sample was characterized through descriptive statistics. Then, Shapiro-Wilk and the Levene tests were used to analyse normality and homoscedasticity, respectively. Then, repeated measures ANOVA with Bonferroni correction post hoc were used to compare player positions, player status and the 10 mesocycles, respectively. A *p*-value $\leq$ 0.05 was considered for analysis.

In addition, tt was calculated the Hedge's g effect size with 95% of confidence interval. The following thresholds of Hopkins were applied: $\leq$0.2, trivial; $>$0.2, small; $>$0.6, moderate; $>$1.2, large; $>$2.0, very large and $>$4.0, nearly perfect [39].

The statistical power of 96% was found for a post hoc F-test family (α level = 0.05; effect size = 1.3; five groups (playing position), and a sample of 17 participants). Then, the procedure was repeated for the post hoc F-test family (α level = 0.05; effect size = 0.6; two groups (playing status), and a sample of 17 participants) which provide an actual power of 100%. All calculation were made through G-Power [40].

3. Results

Fig. 1 showed a general variation of the weekly average for TM, TS calculated through the fatigue, stress, DOMS and sleep quality by playing status. Overall, Fig. 1A showed the main results in M7 where significant higher TM

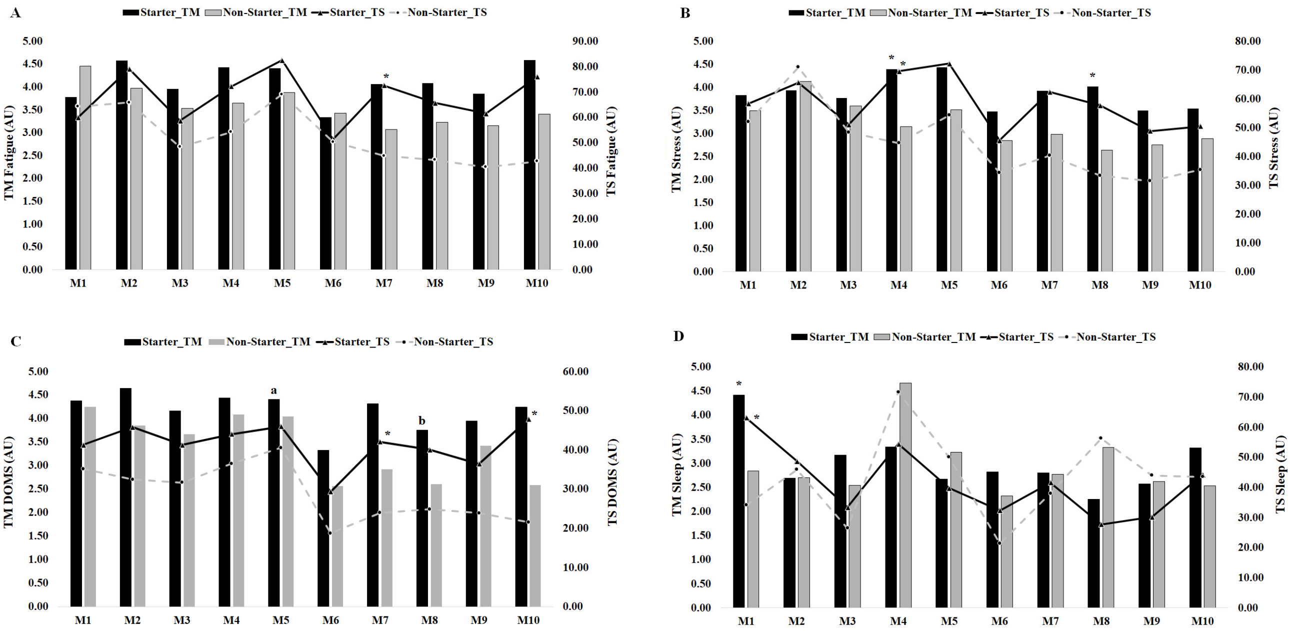

Fig. 1. TM (training monotony) and TS (training strain) variations calculated through the HI categories across 10 mesocycles (M1-10) for starters and non-starters. (A) Fatigue. (B) Stress. (C) DOMS. (D) Sleep. * denote significant difference from non-starters ($p < 0.05$); # denote significant difference from M8 ($p < 0.05$).

value with very large effect was found for starters than non-starters (p = 0.041, ES = 3.01).

In Fig. 1B, M4 showed significant higher TM with very large effect ($p < 0.039$, ES = 3.1) and TS with very large effect ($p < 0.039$, ES = 3.02) values for starters than non-starters. TS also showed significantly higher values with very large effect in M8 for starters than non-starters (p = 0.039, ES = 3.21).

In Fig. 1C, TM showed significantly higher values with very large effect for starters than non-starters in M7 (p = 0.05, ES = 2.61) and M10 (p = 0.036, ES = 2.83). TS also showed significantly higher values with very large effect in M7 for starters than non-starters (p = 0.018, ES = 3.57).

In Fig. 1D, TM and TS showed significantly higher values with very large effect in M1 for starters than non-starters (p = 0.010, ES = 3.65 and p = 0.039, ES = 3.03, respectively).

Regarding inter-mesocycles comparisons for starters, there was a higher value with very large effect size of TM sleep (Fig. 1D) in M1 than M8 (p = 0.049, ES = 3.25). No other differences were found for starters neither for non-starters.

Fig. 2 showed ACWR variations calculated through the different HI categories. In Fig. 2A, M7 showed a significantly higher value with very large effect for starters than non-starters (p = 0.024, ES = 3.03). In Fig. 2C, M2, M7 and M9 showed significant higher values with very large effects for starters than non-starters (p = 0.020, ES = 3.19; p = 0.041, ES = 2.74; p = 0.019, ES = 3.18, respectively).

Regarding inter-mesocycles comparisons for starters, there was a higher value with very large effect size in M5 than M10 (p = 0.05, ES = 3.15) for ACWR stress (Fig. 2B). No other differences were found for starters neither for non-starters.

Fig. 3 showed TM, TS, and ACWR variations calculated through fatigue for player positions. No significant differences were found.

Fig. 4 showed TM, TS, and ACWR variations calculated through stress for player positions. There was a significant difference between wide defenders vs central midfielders for TM (p = 0.033, ES = 5.16) and central defenders vs wide defenders for ACWR (p = 0.044, ES = 4.95), both with nearly perfect effects.

Fig. 5 showed TM, TS, and ACWR variations calculated through DOMS for player positions. No significant differences were found.

Fig. 6 showed TM, TS, and ACWR variations calculated through sleep for player positions. There was a significant difference between wide defenders and strikers for TM in M2 with a nearly perfect effect (p = 0.015, ES = 5.80).

4. Discussion

The main goals of the present study were: (a) to describe and compare the in-season variations of TM, TS, and ACWR through fatigue, stress, DOMS, and sleep quality; (b) to compare those variations between player positions and status (starters and non-starters). First, according to the best of knowledge of the authors, there is no research that

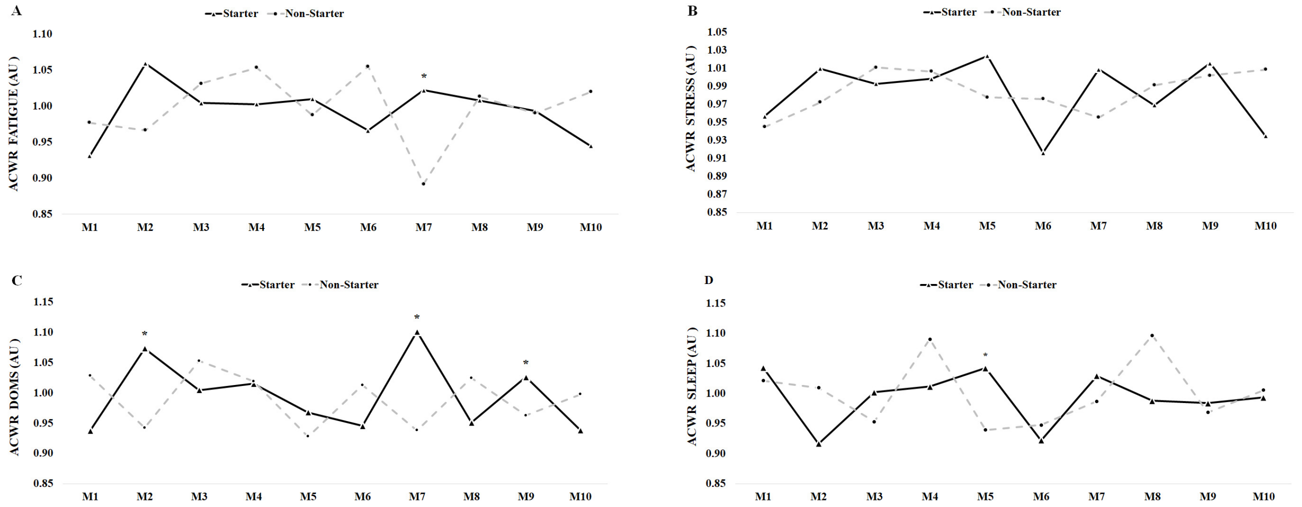

Fig. 2. Acute: Chronic Workload Ratio (ACWR) variations calculated through the HI categories across 10 mesocycles (M1-10) for starters and non-starters. (A) Fatigue. (B) Stress. (C) DOMS. (D) Sleep. * denote significant difference from non-starters ($p < 0.05$); # denote significant difference from M10 ($p < 0.05$).

analyses differences between player positions and starters *vs* non-starters through TM, TS, ACWR calculated with HI categories across a full soccer season. In addition, the major finding of the present study revealed that the indexes calculated through the HI showed a significant variation according to the player status and playing positions across in-season.

The analysis of internal intensity measured by psychophysiological variables such as s-RPE is usually highly preferred because of its potential to integrate different stimulus types, being easye of use and considered as a global measure of intensity in team sports [8,9]. However, Haddad *et al*. [41] recommended that s-RPE was not susceptible enough to identify indicators of wellness such as subjective fatigue, DOMS, stress, and sleep levels in junior soccer players. In this context, Hooper & Mackinnon [14] asserted a self-assessment-based psychometric questionnaire that includes well-being related to sleep, stress, fatigue, and muscle soreness called HI.

Specifically, the main results showed high TM of fatigue and DOMS values in M2 which may be related to the fact that starters have played quite a lot of matches in M2, and the accumulated training duration was higher in this mesocycle which also resulted in 2 non traumatic injuries. The high TM of sleep and TS of sleep values in M1 may be due to the high pre-season training intensity. In fact, M1 denoted the highest value of the season for starters compared to the other mesocycles and in fact it was coincident with 4 non traumatic injuries, but no other statistically significant differences were found for the other TM measures. In addition, it was observed that TM of fatigue and DOMS categories were high in M1 and the stress category in M2. Higher levels of these categories in M1 and M2 could be related to exposure to higher training intensity to improve the physical condition rather than participation in playtime. Also, this higher intensity could be associated to the pre-season period that triggers more difficult and tiresome demands when compared to the in-season professional soccer period [25,27,29,42].

Regarding the mesocycle analysis, starter players had significantly higher TM of fatigue (M7), DOMS (M5 and M8), stress (M4) and higher TS of stress (M4 and M8), and DOMS (M7) than non-starter players during in-season period. The high TM of DOMS, stress, and TS of stress value in M5 indicated that the starters were exposed to high match and training intensity during the first period of the season. It was observed that the accumulated training time was low in M5 and M6, and the number of matches played was high. This showed that the intensity was reduced in training sessions. Starters showed the lowest TM of fatigue, stress, DOMS and TS of stress and DOMS values in M6, which clearly shows that the optimization of the intensity was well adjusted by the coach and his staff in the middle of the season, and enough rest activities were given to players recover. Meanwhile, M6 showed 4 injuries for non-starters while starters presented no injuries which means that TM is not always sensitive to detect injuries as originally proposed by Foster [9]. Compared with non-starters, TM of fatigue, DOMS and TS of DOMS and stress values increased again in starters towards the end of the season. The result is consistent with Nobari *et al*. [18] who stated that greater weekly acute intensity, fatigue, stress, and HI variations were found at the end of the season.

In addition, starters showed higher TM and TS values over the in-season than non-starters, although there were some exceptions (see Fig. 1). This parallels the results of the study conducted by Nobari *et al*. [27] who indicated that starters exhibited significantly greater values of TM

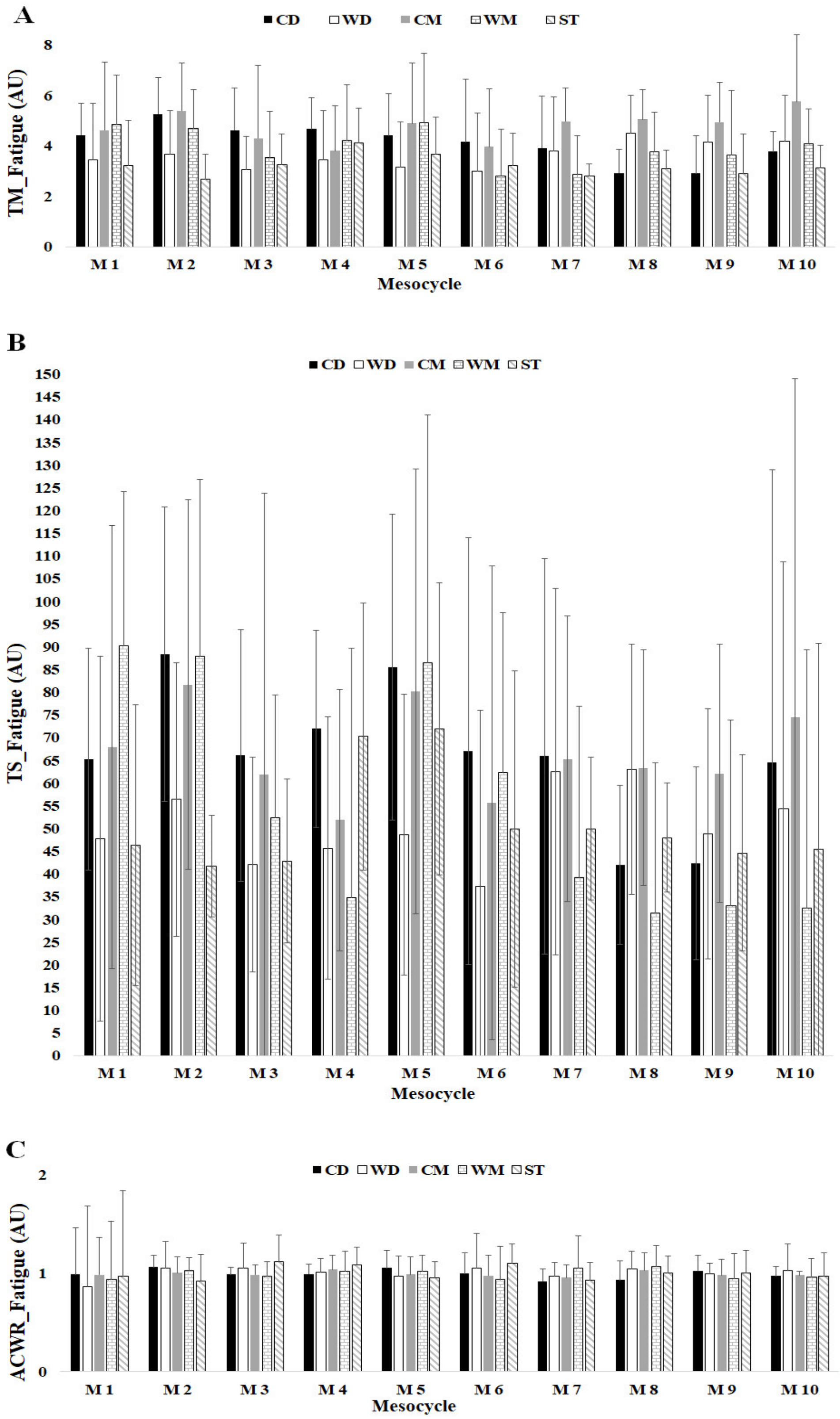

Fig. 3. Training Monotony (TM), Training Strain (TS) and Acute: Chronic Workload Ratio (ACWR) variations calculated through fatigue category across 10 mesocycles (M1-10) for player positions. (A) TM. (B) TS. (C) ACWR. CD, central defenders; WD, wide defenders; CM, central midfielders; WM, wide midfielders; ST, strikers.

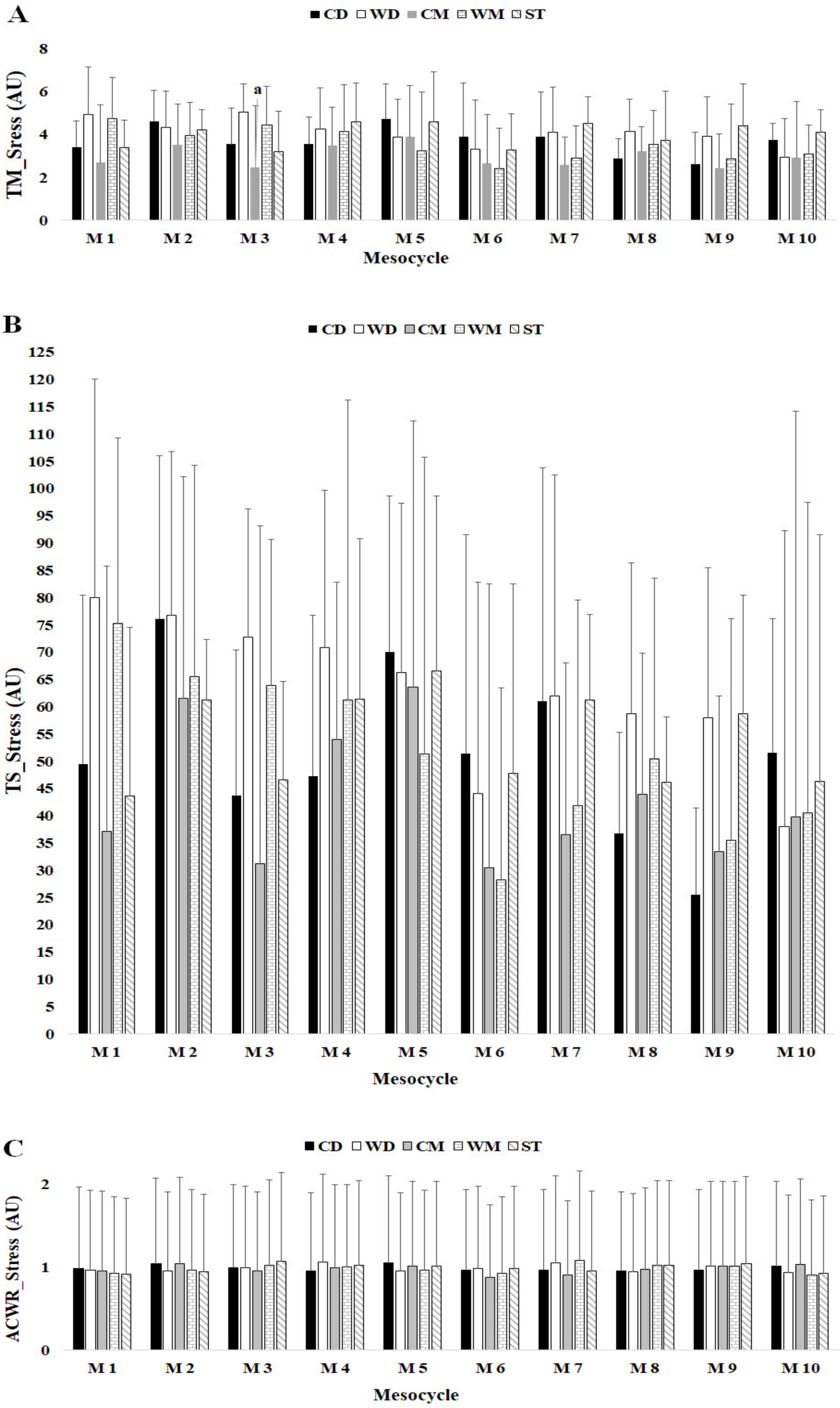

Fig. 4. Training Monotony (TM), Training Strain (TS) and Acute: Chronic Workload Ratio (ACWR) variations calculated through stress category across 10 mesocycles (M1-10) for player positions. (A) TM. (B) TS. (C) ACWR. (a) denote significant difference from WD ($p < 0.05$). CD, central defenders; WD, wide defenders; CM, central midfielders; WM, wide midfielders; ST, strikers.

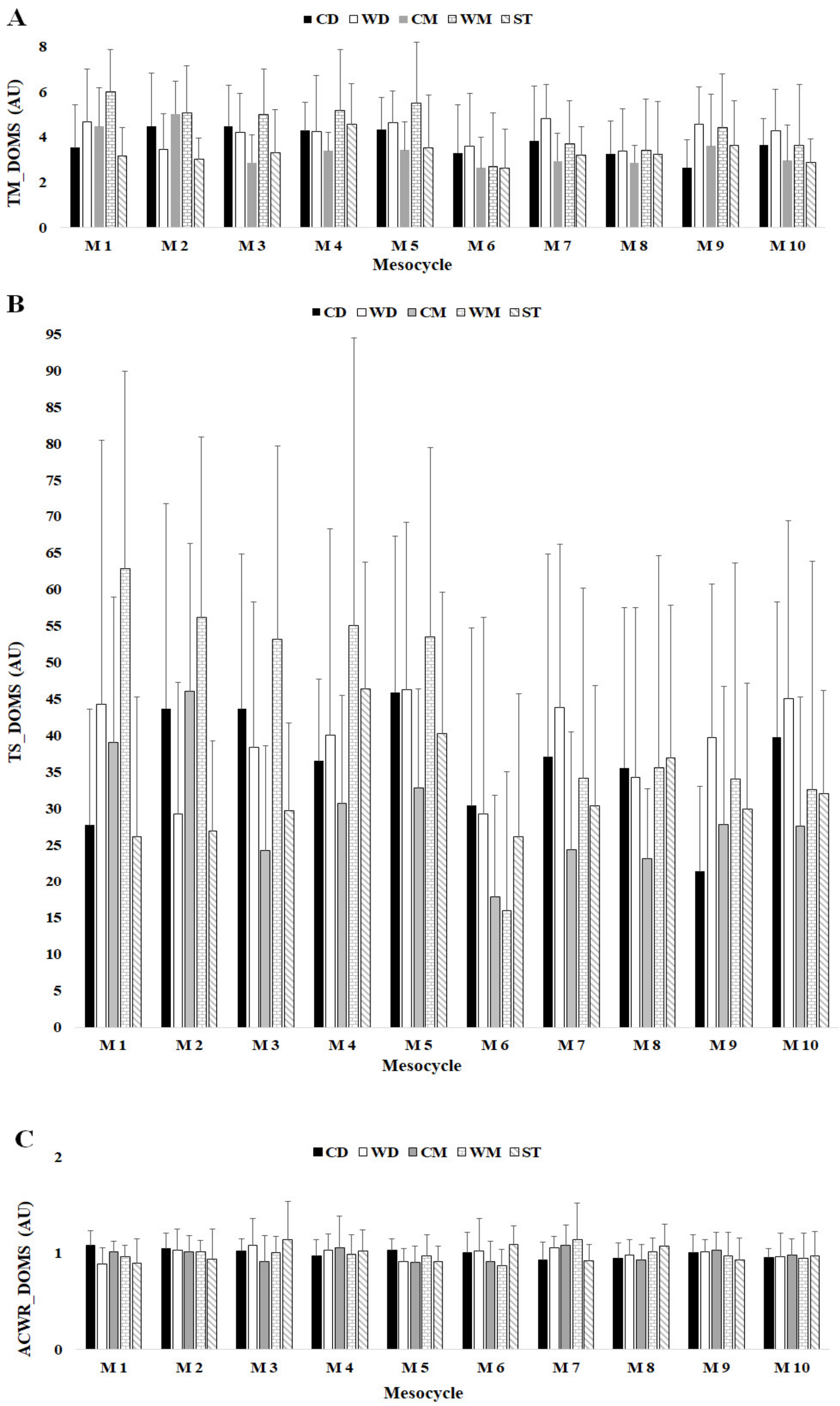

Fig. 5. Training Monotony (TM), Training Strain (TS) and Acute: Chronic Workload Ratio (ACWR) variations calculated through DOMS category across 10 mesocycles (M1-10) for player positions. (A) TM. (B) TS. (C) ACWR. CD, central defenders; WD, wide defenders; CM, central midfielders; WM, wide midfielders; ST, strikers.

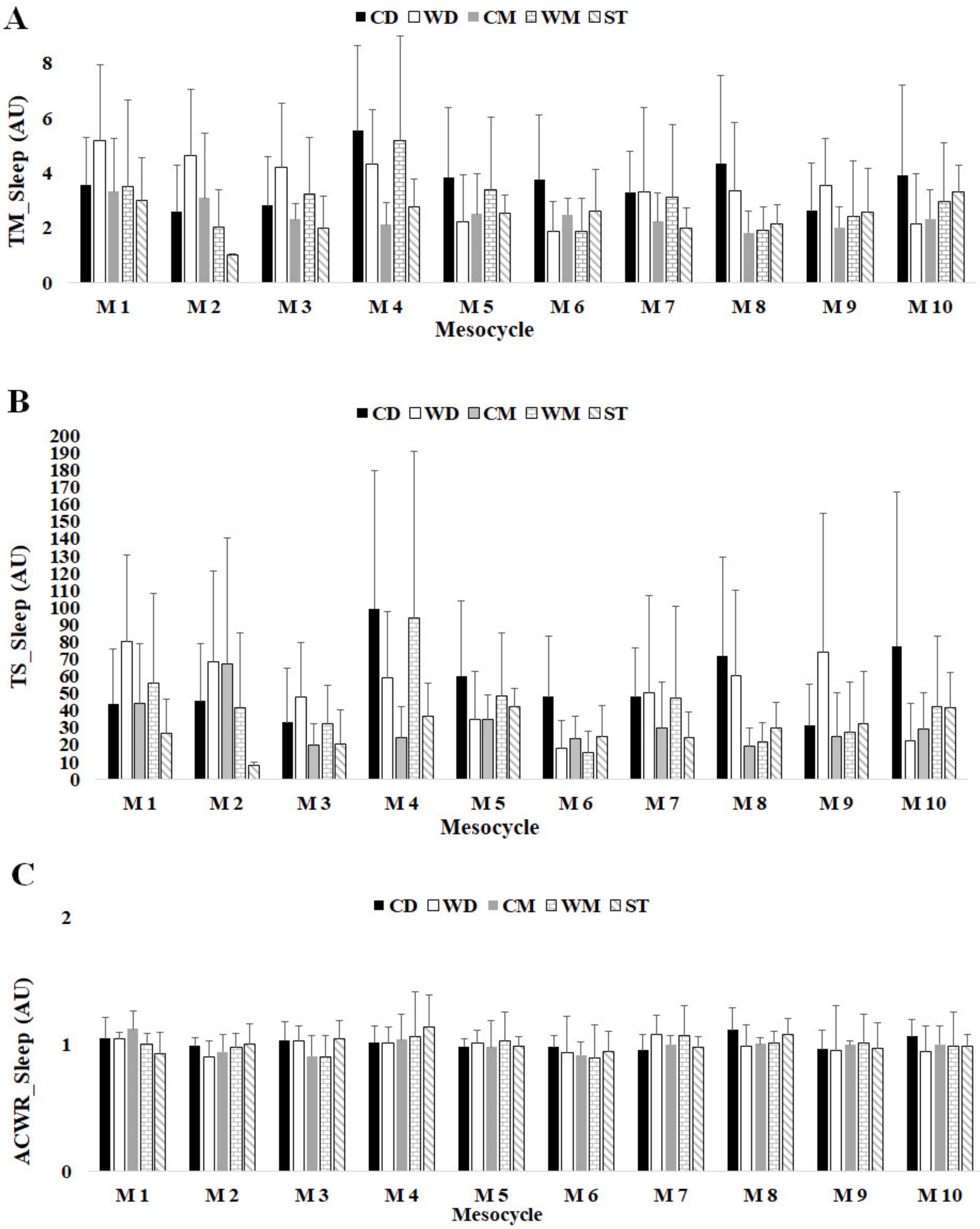

Fig. 6. Training Monotony (TM), Training Strain (TS) and Acute: Chronic Workload Ratio (ACWR) variations calculated through sleep quality category across 10 mesocycles (M1-10) for player positions. (A) TM. (B) TS. (C) ACWR. (b) denote significant difference from ST ($p < 0.05$). CD, central defenders; WD, wide defenders; CM, central midfielders; WM, wide midfielders; ST, strikers.

and TS based on the number of accelerations and decelerations across four periods of the season. A possible reason for the present results may be related to the match playtime. Previous studies showed that match playtime was related to the weekly greatest amount of high intensity running and sprint distances [26,43]. Recent studies showed that starters spent more time in high intensity zones than non-starters and also, they exhibited greater high-speed running, number of accelerations, repeated sprints, and sprinting compared to non-starters in matches during in-season period in professional soccer players [26,33,43]. Consequently, it is considered important that training programs can be specifically constituted for non-starter to cause an adequately intensive training stimulus to produce adaptations that retain and enhance the whole soccer-specific fitness of the team. Moreover, additional training associated with the high-speed variables appears to be important for non-starters, once the high intensity running distance collected from a match corresponds to 3.4 times the "on-field" soccer training [26]. The biochemical justification of the high levels TM and TS in starters during the in-season period can be explained by the study conducted by Vilamitjana *et al*. [44], who found that testosterone and testosterone/cortisol index of non-starters were found to be higher compared to starters during the in-season period, but not during pre-season. They claimed that non-starters were inadequate in terms of hormonal and enzymatic (biomarkers that detect cellular damage) conditions during the in-season due to their low match durations. Coaches and their staff should arrange their training program to enhance, and to implement similar training intensities to non-starter players during in-season [27].

The ACWR can be beneficial in explaining the risks associated with the injury rate of athletes such as sudden increases in intensity or critical intensity reductions and describing weekly changes (to check advancement or over intensity strategies) [42]. Starters exhibited significantly greater values for ACWR of DOMS than non-starters in M2, M7, M9, and also ACWR of fatigue values were found to be significantly greater in starters than non-starters in M7. On one hand, each mesocycle showed 2 injuries for starters, but on the other hand, higher values of injuries were reported in M1, M3, M4, M6, M7 and M9 (range of 4–6 injuries) which once again does not confirm that ACWR has higher sensibility to detect injuries [45–51].

The highest ACWR of fatigue, stress, and DOMS values in M2 in starter players may be related to the accumulated training duration and the number of matches in this mesocycle. Significantly highest ACWR of fatigue and ACWR of DOMS values in M7 and M9 may be due to the fact that the starter players had more matches (specifically, M6 = 8 matches, M9 = 7 matches) in the congested weeks, and they were preferred by the coach in critical matches towards the end of the season. Due to high ACWR values, DOMS and fatigue can trigger the risk of injury in starter players towards the end of the season. Considering that the starters perform higher intense activities during the match playtime, the risk of injury may be higher for them than non-starters. This was also demonstrated in the study of Malone *et al*. [52]. They remarked that exposing players to great and quick rises in high-speed running and sprint running distances increased the possibility of the injury. However, they recommended that greater weekly chronic load ($\geq$2584 AU), and better aerobic capacity reduced lower limb injury risk in elite soccer players [52]. In the same line, Nobari *et al*. showed that high volume of sprinting during high intensity weeks was associated with non-contact injury occurrence [53]. Moreover, Ferreira *et al*. [42] found that well-being measures such as higher DOMS and fatigue values were associated with acute load and ACWR values in professional basketball players. Thus, they reported that significant decreases were determined in acute load from pre-season to the in-season, while DOMS and fatigue levels were high. The results of Ferreira *et al*. [42] supported the findings of our study for starter players. For the reasons mentioned before, it is recommended to analyse variations in the wellness status of the players during the in-season for the top level soccer performance [42].

Regarding player positions, there were some variations across in-season that could be associated with the differences in physiological and functional capacity in players with different positions [18]. Especially, wide defenders had greater ACWR of stress values than central defenders in M4 which was also followed by two injuries vs none. They had significantly greater TM of stress values than central midfielders in M3, and TM of sleep values than strikers in M2 (no injuries were noted for wide defenders). After analysing the higher values and the number of injuries, it was possible to observe that such measures were not associated with some mesocycles where injuries were found (e.g., 4 injuries for strikers in M1 or only 2 injuries during the entire in-season for wide defenders in M4).

In the first half of the season, indexes of wide defenders were found to be high as compared with other positions. In addition, it stood out that wide midfielders had greater TS of fatigue, stress, DOMS and greater TM of DOMS in M1. As far as we know, no study calculated TM, TS, ACWR of the players according to their playing positions using wellness indicators. Clemente *et al*. [29] observed that wide defenders had greater acute inensities of impacts and TS than central defenders, wingers, and strikers. Oliveira *et al*. [31] found that training intensity variables showed limited variation between player positions. When they compared the high-speed running zones (>19 km/h) during the mesocycle analysis according to playing positions, they suggested that wide defenders (212.7 m) and wide midfielders (186.8 m) had greater effort during training than other positions (central defenders = 112.2, central midfielders = 164.1, strikers = 116.1 m). The results of previous studies were in line with the results of this study [29,31]. Based on that, we can mention that wide defenders and wide midfielders have a higher high-intensity training profile. In the present study, compared to other positions, the reason for the wide defenders and wide midfielders displayed higher indexes in the first half of the season (especially, in M1) may be related to the high training and match demands of the position they serve. Also, both playing positions perform higher-intensity activities during the matches due to their duties in both defensive and offensive.

To our knowledge, this is the first study to investigate TM based on well-being measures, and provides reference values. This study revealed the lowest and highest TM (fatigue, stress, DOMS, and sleep) of starters during the in-season ranged between 2.25 AU and 4.65 AU, and non-starter players ranged between 2.33 AU and 4.67 AU in top elite soccer players. The results of this study are in line with Nobari, Oliveira, *et al.* [18], who reported that the lowest and highest TM values based on accelerations in zone 1 in starters varied between 1.87–3.25 AU, while in non-starters it varied between 0.98–2.18 AU. Foster [9] suggested that a monotony index higher than 2 AU was an element of risk for illness and overtraining in players. Clemente *et al.* [54] expressed that TM was found to range between 0.9 and 3.8 AU (mean of 2 AU) in professional soccer players across a 10-week period. Nobari *et al.* [16] detected that TM values of elite under-16 soccer players were between 1.06 and 1.19 AU across the 20-week period. In the current study, it was observed that TM values were greater than 2 AU. The reason for this may be related to the method to calculate TM where HI categories were used, the applied training plan, the sample group (top-elite soccer players), quality of the league, and the level of opponent teams. Also, the present study showed that starters had higher TM values in the majoraty of the mesocycles than non-starters. An appropriate strategy may be for the coaches and their staff to apply complementary training on the non-starters to compensate for the intensity gap between starters and non-starters during in-season period [55].

The present study also provides reference values for ACWR. In this study, the lowest and highest ACWR (fatigue, stress, DOMS, and sleep) of starters during the in-season ranged between 0.92 and 1.07 AU, and non-starter players ranged between 0.89 and 1.10 AU. The study of Hasan *et al.* [39] overlaps with our findings. They clarified a ACWR of 0.95–1.09 AU over 23-weeks for different external parameters. In literature, some studies showed that higher ACWR were associated with increased injury risk [38,56,57]. For instance, Timoteo *et al.* [56] reported that higher ACWR value and poor recovery were related to greater odds of injury, and also players who suffered injuries had higher ACWR values than uninjured players in the previous week. Also, Myers *et al.* [38] showed that injured players had a mean ACWR of 1.57 AU in the week before the injury occurred and as a result, they showed that ACWR (especially an acute increase) from the previous week and previous injury history were significant predictors of injury the following week. Bowen *et al.* [58] showed that the risk of non-contact injuries increased when ACWR by calculated from GPS data was $>$2.0 AU. Additionally, they found that the risk of contact injuries augmented when ACWR was 1.1–1.5 AU in elite soccer players, over three seasons. Other study demonstrated that ACWR $>$2.0 was associated with higher risk of injury, while ACWR $\geq$1.35 to $\leq$1.50 AU could be considered to prevent injury risk during the pre- and early periods of the in-season [42]. Meanwhile, ACWR-injury association did constitute the ability to detect injury occurrence [59] which was reinforced by recent studies [45–51]. They added that ACWR was an insufficient measure to predict injury risk due to methodological heterogeneity (defining time windows for acute and chronic periods, injury types investigated, data estimation methods, and statistical analysis *etc.*) in previous studies [45–51] which was confirmed by the presented study considering TM, TS or ACWR calculated through well-being measures. Considering the studies in the literature, it was observed that the ACWR values calculated by the HI were not very high for starter and non-starter players during in-season period. This shows that the optimization between training intensity, well-being and recovery was well adjusted throughout the in-season period.

Meanwhile and considering the previous information, it is very important that prognostic studies should be increased in order to predict the risk of injury through different parameters especially ACWR in different sports branches, and to clarify the underlying mechanisms. As previouly mentioned, other analysis such as the odds ratios of non-contact injuries through different training intensity measures [53] as well as through well-being variables should be considered for future studies.

There are some limitations that should be pointed. The sample size was small and belongs to only one team which may have influence the results. Clemente *et al.* [19] stated that this issue is one of the frequently reported limitations of longitudinal studies over a full season in professional contexts. Second, pre-season was not analyzed. Finally, the non-use of other internal (heart rate) or external measures (running distance or accelerometry-based variables) to support the well-being measures is recommended for future studies. Despite the limitations noted above, the current study is the first to analyze differences between player status and player positions through TM, TS, ACWR calculated with HI categories during a soccer in-season period. To generalize the results, more studies need to be performed considering similar designs, the gender and the age factor in teams from different leagues.

5. Conclusions

Differences in playing positions and player status for coaches and their staff should be considered when establishing training intensity throughout the season period. Indexes such as TM, TS, and ACWR can help to better understand the between and within variations through the season of professional soccer players.Therefore, a comprehensive analysis of players' according to well-being parameters can provide clear information to the coaches and their staff in terms of training monitoring that is not reached with other variables such s-RPE, session duration and number of injuries.

Author contributions

Conceptualization and methodology—RO. Software—RO, AM and MN. Validation—RO, AM and JPB. Formal Analysis—RO and MN. Investigation—RO, HİC, AM, JPB, MN, BM and FMC. Resources—RO, HİC, AM, JPB, BM and FMC. Data Curation—BM. Writing Original Draft—RO, HİC and FMC. Writing Review and Editing—RO, HİC, AM, JPB, MN and FMC. Visualization—RO, JPB and FMC. Supervision—RO. Project Administration—RO and JPB. Funding Acquisition—RO and JPB. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was conducted according to the requirements of the Declaration of Helsinki and was approved by the Ethics Committee of Polytechnic Institute of Santarém (252020Desporto). All players signed an informed consent prior to the investigation.

Acknowledgment

The authors would like to thank the team's coaches and players for their cooperation during all data collection procedures.

Funding

This project was supported by the Portuguese Foundation for Science and Technology, I.P., Grant/Award Numbers UIDP/04748/2020. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

Due to issues of participant consent related to the new data protection law from 25th may, 2018 from the Portuguese data protection law nº. 58/2019 of 8 August, in accordance with the Council and European Parliament (EU) Regulation 2016/679, 27th April 2016, on the protection of individuals regarding the processing of personal data and on the free movement of such data, data will not be shared publicly. Interested researchers may contact the corresponding author.

References

[1] Gabbett TJ, Nassis GP, Oetter E, Pretorius J, Johnston N, Medina D, *et al*. The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. British Journal of Sports Medicine. 2017; 51: 1451–1452.

[2] Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. British Journal of Sports Medicine. 2010; 44: 809–815.

[3] Miguel M, Oliveira R, Loureiro N, García-Rubio J, Ibáñez SJ. Load Measures in Training/Match Monitoring in Soccer: A Systematic Review. International Journal of Environmental Research and Public Health. 2021; 18: 2721.

[4] Staunton CA, Abt G, Weaving D, Wundersitz DWT. Misuse of the term 'load' in sport and exercise science. Journal of Science and Medicine in Sport. 2021. (in press)

[5] Borresen J, Ian Lambert M. The Quantification of Training Load, the Training Response and the Effect on Performance. Sports Medicine. 2009; 39: 779–795.

[6] Mujika I. Quantification of Training and Competition Loads in Endurance Sports: Methods and Applications. International Journal of Sports Physiology and Performance. 2017; 12: S2–17.

[7] Weaving D, Jones B, Marshall P, Till K, Abt G. Multiple Measures are Needed to Quantify Training Loads in Professional Rugby League. International Journal of Sports Medicine. 2017; 38: 735–740.

[8] Borges TO, Moreira A, Thiengo CR, Medrado RGSD, Titton A, Lima MR, *et al*. Training intensity distribution of young elite soccer players. Revista Brasileira de Cineantropometria & Desempenho. 2019; 21: 1–11. (In Português)

[9] Foster C. Monitoring training in athletes with reference to overtraining syndrome. Medicine & Science in Sports & Exercise. 1998; 30: 1164–1168.

[10] Haddad M, Stylianides G, Djaoui L, Dellal A, Chamari K. Session-RPE Method for Training Load Monitoring: Validity, Ecological Usefulness, and Influencing Factors. Frontiers in Neuroscience. 2017; 11: 612.

[11] Rabbani A, Kargarfard M, Twist C. Fitness Monitoring in Elite Soccer Players: Group vs. Individual Analyses. Journal of Strength and Conditioning Research. 2020; 34: 3250–3257.

[12] Giles S, Fletcher D, Arnold R, Ashfield A, Harrison J. Measuring well-being in Sport Performers: where are we now and how do we Progress? Sports Medicine. 2020; 50: 1255–1270.

[13] Duignan C, Doherty C, Caulfield B, Blake C. Single-Item Self-Report Measures of Team-Sport Athlete Wellbeing and their Relationship with Training Load: a Systematic Review. Journal of Athletic Training. 2020; 55: 944–953.

[14] Hooper SL, Mackinnon LT. Monitoring Overtraining in Athletes. Sports Medicine. 1995; 20: 321–327.

[15] Rabbani A, Clemente FM, Kargarfard M, Chamari K. Match Fatigue Time-Course Assessment Over Four Days: Usefulness of the Hooper Index and Heart Rate Variability in Professional Soccer Players. Frontiers in Physiology. 2019; 10: 109.

[16] Nobari H, Aquino R, Clemente FM, Khalafi M, Adsuar JC, Pérez-Gómez J. 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. Physiology & Behavior. 2020; 225: 113117.

[17] Windt J, Gabbett TJ, Ferris D, Khan KM. Training load–injury paradox: is greater preseason participation associated with lower in-season injury risk in elite rugby league players? British Jour-

nal of Sports Medicine. 2017; 51: 645–650.
[18] Nobari H, Fani M, Pardos-Mainer E, Pérez-Gómez J. Fluctuations in Well-Being Based on Position in Elite Young Soccer Players during a Full Season. Healthcare. 2021; 9: 586.
[19] Clemente FM, Silva R, Castillo D, Los Arcos A, Mendes B, Afonso J. Weekly Load Variations of Distance-Based Variables in Professional Soccer Players: A Full-Season Study. International Journal of Environmental Research and Public Health. 2020; 17: 3300.
[20] Oliveira R, Martins A, Nobari H, Nalha M, Mendes B, Clemente FM, *et al*. In-season monotony, strain and acutechronic workload of perceived exertion, global positioning system running based variables between player positions of a top elite soccer team. BMC Sports Science, Medicine and Rehabilitation. 2021; 13: 126.
[21] Oliveira R, Palucci Vieira LH, Martins A, Brito JP, Nalha M, Mendes B, Clemente FM. In-Season Internal and External Workload Variations between Starters and Non-Starters-A Case Study of a Top Elite European Soccer Team. Medicina. 2021; 57: 1–15.
[22] Hader K, Rumpf MC, Hertzog M, Kilduff LP, Girard O, Silva JR. Monitoring the Athlete Match Response: can External Load Variables Predict Post-match Acute and Residual Fatigue in Soccer? A Systematic Review with Meta-analysis. Sports Medicine - Open. 2019; 5: 48.
[23] Clemente FM, Martinho R, Calvete F, Mendes B. Training load and well-being status variations of elite futsal players across a full season: Comparisons between normal and congested weeks. Physiology & Behavior. 2019; 201: 123–129.
[24] Nobari H, Fani M, Clemente FM, Carlos-Vivas J, Pérez-Gómez J, Ardigò LP. Intra- and Inter-week Variations of Well-Being Across a Season: A Cohort Study in Elite Youth Male Soccer Players. Frontiers in Psychology. 2021; 12: 671072.
[25] Fessi MS, Nouira S, Dellal A, Owen A, Elloumi M, Moalla W. Changes of the psychophysical state and feeling of wellness of professional soccer players during pre-season and in-season periods. Research in Sports Medicine. 2016; 24: 375–386.
[26] Dalen T, Lorås H. Monitoring Training and Match Physical Load in Junior Soccer Players: Starters versus Substitutes. Sports. 2019; 7: 70.
[27] Nobari H, Oliveira R, Clemente FM, Adsuar JC, Pérez-Gómez J, Carlos-Vivas J, *et al*. Comparisons of accelerometer variables training monotony and strain of starters and non-starters: A full-season study in professional soccer players. International Journal of Environmental Research and Public Health. 2020; 17: 1–14.
[28] Clemente FM, Mendes B, Nikolaidis PT, Calvete F, Carriço S, Owen AL. Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. Physiology & Behavior. 2017; 179: 262–267.
[29] Clemente F, Silva R, Ramirez-Campillo R, Afonso J, Mendes B, Chen Y. Accelerometry-based variables in professional soccer players: Comparisons between periods of the season and playing positions. Biology of Sport. 2020; 37: 389–403.
[30] Hasan UC, Silva R, Clemente F. Weekly variations of biomechanical load variables in professional soccer players: comparisons between playing positions. Human Movement. 2021; 22: 19–34.
[31] Oliveira R, Brito JP, Martins A, Mendes B, Marinho DA, Ferraz R, *et al*. In-season internal and external training load quantification of an elite European soccer team. PLoS ONE. 2019; 14: 0209393.
[32] Nobari H, Praça GM, Clemente FM, Pérez-Gómez J, Carlos Vivas J, Ahmadi M. Comparisons of new body load and metabolic power average workload indices between starters and non-starters: a full-season study in professional soccer players. Proceedings of the Institution of Mechanical Engineers, Part P. 2020; 235: 105–113.
[33] Nobari H, Castillo D, Clemente FM, Carlos-Vivas J, Pérez-Gómez J. Acute, chronic and acute/chronic ratio between starters and non-starters professional soccer players across a competitive season. Proceedings of the Institution of Mechanical Engineers, Part P. 2021.
[34] Foster C, Florhaug Ja, Franklin J, Gottschall L, Hrovatin La, Parker S, *et al*. A New Approach to Monitoring Exercise Training. the Journal of Strength and Conditioning Research. 2001; 15: 109.
[35] Foster C, Hector LL, Welsh R, Schrager M, Green MA, Snyder AC. Effects of specific versus cross-training on running performance. European Journal of Applied Physiology and Occupational Physiology. 1995; 70: 367–372.
[36] Impellizzeri FM, Marcora SM, Coutts AJ. Internal and External Training Load: 15 Years on. International Journal of Sports Physiology and Performance. 2019; 14: 270–273.
[37] Dalen-Lorentsen T, Bjørneboe J, Clarsen B, Vagle M, Fagerland MW, Andersen TE. Does load management using the acute:chronic workload ratio prevent health problems? a cluster randomised trial of 482 elite youth footballers of both sexes. British Journal of Sports Medicine. 2021; 55: 108–114.
[38] Myers NL, Aguilar KV, Mexicano G, Farnsworth JL, Knudson D, Kibler WB. The Acute:Chronic Workload Ratio is Associated with Injury in Junior Tennis Players. Medicine & Science in Sports & Exercise. 2020; 52: 1196–1200.
[39] Hopkins Wg, Marshall Sw, Batterham Am, Hanin J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. Medicine & Science in Sports & Exercise. 2009; 41: 3–12.
[40] Faul F, Erdfelder E, Lang A, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods. 2007; 39: 175–191.
[41] Haddad M, Chaouachi A, Wong DP, Castagna C, Hambli M, Hue O, *et al*. Influence of fatigue, stress, muscle soreness and sleep on perceived exertion during submaximal effort. Physiology & Behavior. 2013; 119: 185–189.
[42] Ferreira M, Camões M, Lima RF, Silva R, de Oliveira Castro H, Mendes B, *et al*. Variations of workload and well-being measures across a professional basketball season. Revista Brasileira de Cineantropometria & Desempenho. 2021; 23.
[43] Anderson L, Orme P, Michele RD, Close GL, Milsom J, Morgans R, *et al*. Quantification of Seasonal-Long Physical Load in Soccer Players with Different Starting Status from the English Premier League: Implications for Maintaining Squad Physical Fitness. International Journal of Sports Physiology and Performance. 2016; 11: 1038–1046.
[44] Vilamitjana J, Vaccari JC, Toedtli M, Navone D, Rodriguez-Buteler JM, Verde PE, *et al*. Monitoring biochemical markers in professional soccer players during the season and preseason preparation phase. Revista Internacional de Ciencias del Deporte. 2017; 13: 211–224. (In Spanish)
[45] Impellizzeri FM, Ward P, Coutts AJ, Bornn L, McCall A. Training Load and Injury Part 1: the Devil is in the Detail—Challenges to Applying the Current Research in the Training Load and Injury Field. Journal of Orthopaedic & Sports Physical Therapy. 2020; 50: 574–576.
[46] Impellizzeri FM, Ward P, Coutts AJ, Bornn L, McCall A. Training Load and Injury Part 2: Questionable Research Practices Hijack the Truth and Mislead well-Intentioned Clinicians. Journal of Orthopaedic & Sports Physical Therapy. 2020; 50: 577–584.
[47] Enright K, Green M, Hay G, Malone JJ. Workload and Injury in Professional Soccer Players: Role of Injury Tissue Type and Injury Severity. International Journal of Sports Medicine. 2020; 41: 89–97.

[48] Fanchini M, Rampinini E, Riggio M, Coutts AJ, Pecci C, McCall A. Despite association, the acute:chronic work load ratio does not predict non-contact injury in elite footballers. Science and Medicine in Football. 2018; 2: 108–114.
[49] Impellizzeri FM, Tenan MS, Kempton T, Novak A, Coutts AJ. Acute:Chronic Workload Ratio: Conceptual Issues and Fundamental Pitfalls. International Journal of Sports Physiology and Performance. 2020; 15: 907–913.
[50] Wang C, Vargas JT, Stokes T, Steele R, Shrier I. Analyzing Activity and Injury: Lessons Learned from the Acute: Chronic Workload Ratio. Sports Medicine. 2020; 50: 1243–1254.
[51] West SW, Williams S, Cazzola D, Kemp S, Cross MJ, Stokes KA. Training Load and Injury Risk in Elite Rugby Union: the Largest Investigation to Date. International Journal of Sports Medicine. 2021; 42: 731–739.
[52] Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. High-speed running and sprinting as an injury risk factor in soccer: can well-developed physical qualities reduce the risk? Journal of Science and Medicine in Sport. 2018; 21: 257–262.
[53] Nobari H, Mainer-Pardos E, Denche Zamorano A, Bowman TG, Clemente FM, Pérez-Gómez J. Sprint Variables Are Associated with the Odds Ratios of Non-Contact Injuries in Professional Soccer Players. International Journal of Environmental Research and Public Health. 2021; 18: 10417.
[54] Clemente FM, Clark C, Castillo D, Sarmento H, Nikolaidis PT, Rosemann T, *et al*. Variations of training load, monotony, and strain and dose-response relationships with maximal aerobic speed, maximal oxygen uptake, and isokinetic strength in professional soccer players. PLoS ONE. 2019; 14: e0225522.
[55] Teixeira JE, Forte P, Ferraz R, Leal M, Ribeiro J, Silva AJ, *et al*. Monitoring Accumulated Training and Match Load in Football: A Systematic Review. International Journal of Environmental Research and Public Health. 2021; 18: 3906.
[56] Timoteo TF, Debien PB, Miloski B, Werneck FZ, Gabbett T, Bara Filho MG. Influence of Workload and Recovery on Injuries in Elite Male Volleyball Players. Journal of Strength and Conditioning Research. 2021; 35: 791–796.
[57] Malone S, Owen A, Newton M, Mendes B, Collins KD, Gabbett TJ. The acute:chonic workload ratio in relation to injury risk in professional soccer. Journal of Science and Medicine in Sport. 2017; 20: 561–565.
[58] Bowen L, Gross AS, Gimpel M, Bruce-Low S, Li FX. Spikes in acute:chronic workload ratio (ACWR) associated with a 5-7 times greater injury rate in English Premier League football players: a comprehensive 3-year study. British Journal of Sports Medicine. 2020; 54: 731–738.
[59] Griffin A, Kenny IC, Comyns TM, Lyons M. The Association between the Acute:Chronic Workload Ratio and Injury and its Application in Team Sports: a Systematic Review. Sports Medicine. 2020; 50: 561–580.