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Using Global Positioning System to Compare Training Monotony and Training Strain of Starters and Non-Starters across of Full-Season in Professional Soccer Players

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Abstract: Soccer is an attractive and popular team sport that has high physiological and fitness stress, and therefore requires special and controlled training programs during the season. The aim of this study was to describe the weekly average and changes in training monotony (TM) and training strain (TS) throughout different periods of the season in professional football players based on the number of accelerations and decelerations, and also to analyze the difference between starters and non-starters players in TM and TS. Nineteen professional players from a soccer team competing in the Iranian Premier League (age, 28 ± 4.6 years; height, 181.6 ± 5.8 cm; body mass, 74.5 ± 5.6 kg, and body mass index, 21.8 ± 1.0 kg/m^2) participated in a cohort study. Participants were divided into two groups based on the time of participation in the weekly competition: starters (N = 10) or non-starters (N = 9). The physical activities of the players were recorded during the training sessions and competitive matches of 43 weeks using GPSPORTS systems Pty Ltd. During pre- and end-season TS was not significantly different between starters and non-starters, while during early- and mid-season starters showed a higher TS than non-starter ($p < 0.05$). TS was higher during early- and mid-season compared to pre- and end-season. In all zones on both the TM and TS variables, non-starters experienced higher change percentages and coefficient of variation. TM during the season in all zones of accelerations was not significantly different between starters and non-starters. while during mid-season starters showed a higher TM than non-starters in all zones of decelerations ($p < 0.05$). TM data showed fluctuations and w-shaped graphs in the week-by-week survey. These results indicate that training during early- and mid-season is not enough for the physical development of non-starters soccer players. Coaches should be more careful when designing training for non-starters players, and they could consider the use of game simulation, preparatory match or intra-team match, or individual training programs.

Keywords: acceleration; deceleration; external monitoring; periodization; performance; GPS

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1. Introduction

Short sprints, fast acceleration or deceleration, twisting, jumping, kicking, and tackling are all features of soccer, which is one of the most popular sports in the world. It is widely considered that soccer has evolved through time to become faster, with more intensity and aggressive play than previously observed. Elite soccer is a complicated sport in which players' success is influenced by a variety of elements, including physical fitness, psychological factors, player technique, and team tactics. Players' ability to compete might also be harmed by injuries and the consequences of past injuries [1]. Injuries incidence have been shown to have a significant impact on team success [2–5] and they cause considerable financial hardship for club executives [2]. According to research conducted in 2020, the financial loss resulting from players injuries in a typical English Premier League team is projected to be around £ 45 million [2].

Excessive training load during the season is the primary cause of most non-contact injuries in soccer players and many professional athletes [6]. Through training monitoring, it is possible to monitor the daily changes of the player and the load that is imposed on him during training and matches [7]. This finding emphasizes the importance of monitoring players in a practical setting. Several studies have linked workload to injury risk in professional soccer players, highlighting the importance of monitoring players' workload to avoid injury [6]. Lu et al. reported that professional soccer players had more workload in the three weeks prior to the injury [8–10]. However, another perspective contends that workloads that underprepared players for the demands of match play could put them at risk of injury and impede results [10,11]. Therefore, optimal training stimulus is crucial to maximizing efficiency by using an acceptable workload while also limiting the detrimental effects of undertraining and overtraining. Understanding the workload–injury relationship is crucial to improve player availability and results [10]. There is a contradiction of investigation on the association between workload and injuries in professional soccer. The International Olympic Committee (2016) published a consensus statement that suggests that the use of the workload monitoring approach is effective in preventing non-contact injuries [12]. However, Impellizzeri et al. [13] concluded that there is no evidence that workload monitoring is used to manage workload and reduce the risk of injury. On the other hand, other researchers believe that excessive and rapid increases in workload may be responsible for most non-contact injuries [14]. Training monotony (TM) helps to ensure that the basic principles of the exercises are observed [2]. Variation, in particular, can be critical for preventing monotony in a training program. Variation can also include periods of rehabilitation for players to encourage supercompensation and to avoid overreaching, as this would place the player in near proximity to overtraining [8]. Concerning training load quantification, there are two basic dimensions that can be considered: internal load (psychobiological responses to a given level of external load) and external load (the physical demand imposed by the task/exercise) [7].

The main tool used to calculate the training load is a rating of perceived exertion (RPE), using a modified perception scale (Borg, CR-10). Workload is calculated using the method proposed by Foster (1998), whereby the session intensity rating is multiplied by the training/match duration (min). In soccer, a correlation has been observed between the absolute workload estimated by the session RPE and injury incidence [15,16]. Malone et al. (2017) showed that a weekly workload higher than 1500 arbitrary units (A.U.) raises the risk of injury in elite soccer players. They also found a direct relationship between the increased likelihood of non-contact injuries with increased TM and training strain (TS) [17].

The TM and TS are considered as external workload. TM is obtained by dividing the average daily work by the standard deviation of daily work. According to research, increased training load monotony is linked to 77% of injuries. The TS is obtained by multiplying the training uniformity in the workload. According to reports, 89% of injuries can be explained by increased TS [18]. Based on these findings, it appears that increased TM or TS may have detrimental effects on athletes' health and fitness. Professional soccer players play 2–3 matches in a week, and they do about 5–6 training sessions during the week, which imposes a high workload on them [8].

Furthermore, in soccer, only 11 players (starters) are allowed to start the competitive match, and they normally have a heavier workload on game day than non-starters [16]. It is important to consider that starters and non-starters will likely have different training and workload patterns per week. As a result, differences in players' workloads may lead to differences in key components of soccer-specific physical fitness between starters and non-starters. Consequently, on the day of the match, when non-starters (players who are not accustomed to match) replace the starters, they may perform the usual physical loads during the match and disrupt team performance [3]. Training load should be monitored to better understand the differences between starters and non-starters, as well as to achieve better training periodization and performance optimization strategies. Different variables, such as total distance, different threshold speed distances covered, acceleration (Acc) and deceleration (Dec), can be assessed using global positioning systems (GPS) as a wearable inertial measurement unit [15].

High-intensity movements such as sprints, Acc, or Dec occur at critical moments in soccer, such as offensive or defensive actions, contests for the ball, or goal-scoring opportunities. Those moments can impact the outcome of a game. Therefore, coaches and researchers are still searching for new and more efficient training approaches to both improve and optimize the maximum Acc and Dec capabilities of professional soccer players during linear sprinting and changes of direction [15,19].

Thus, some research focused on TM and TS in order to provide more and better data on workload indices. Understanding the effect of coaches' training plans and the physiological adaptations of players requires an understanding of load variations within and between weeks, as well as the relationships between these variations and the load distribution. The TM or TS could be interesting indicators to monitor workload in professional soccer players [7,15].

Only one study has included TS and TM with accelerometer variables [15], contrasts between starters and non-starters, and different phases of the season at the same time. According to the information presented above, more studies are needed to explore soccer performance analysis and monitoring [15,16]. Hence, we hypothesized that in all four periods of the season there is a significant difference in the TM and TS of the starter and non-starter groups, and the starters tolerate more TM and TS during the season.

With this explanation, the aim of this study was to describe the weekly average and changes in training monotony (TM) and training strain (TS) throughout different periods of the season in professional football players based on the number of accelerations and decelerations, and also to analyze the difference between starters and non-starters players in TM and TS.

2. Materials and Methods

2.1. Participants

In the 2019–2020 season of the Persian Gulf Premier League in Iran, nineteen professional soccer players (age, 28 $\pm$ 4.6 years; height, 181.6 $\pm$ 5.8 cm, body mass, 74.5 $\pm$ 5.6 kg, and BMI, 21.8 $\pm$ 1.0 kg/m^2) were monitored over 43 weeks. The players had to attend at least three training sessions a week and at least 90% of the season's training sessions to be considered [20]. The exclusion criteria were: (i) any player who did not attend training for at least two weeks due to a long-term injury, or lack of participation in training was ruled out of the sample; (ii) due to variations in operation and variables used in the study, goalkeepers were omitted. This study was carried out by the club's training coaches after consultation with the relevant authorities and the club's head coach [21]. Before beginning the study, the research ethics committee at Ardabil University of Medical Sciences presented approval with the code of IR.ARUMS.REC.1399.546. All players were briefed about the study's intent and signed an informed consent form to participate. The research has been followed on the Helsinki Declaration's (2013) for human studies.

2.2. Experimental Approach to the Problem

This longitudinal study was divided into four periods of 43 full-season weeks to assess the weekly differences in TM and TS between starters and non-starters professional soccer players. These periods were divided as follows: pre-season: w1 to w4; early-season: w5 to w17; mid-season: w18 to w30; and end-season: w31 to w43. It should be noted that due to the spread of the coronavirus, between 34 and 35 weeks, the team's games and training sessions were closed for two months. Table 1 illustrates the training sessions, matches, and overall time sessions for the different periods during the season. Players' week-by-week parameters for specified starters and non-starters varied depending on the time of the match. Participants were divided into two groups according to the total playing time during the weekly matches: starters (N = 10) and non-starters (N = 9). The player had to complete at least 60 min of playing during the match to be counted as starter [22]. During training and competition, GPS (GPSPORTS systems Pty Ltd., model: SPI High-Performance Unit (HPU), manufactured in Australia) was used to record player data. The monitoring was done so that the external load speed of both training sessions and matches could be calculated precisely.

Table 1. Training, match, and total time sessions separately during the periods of the season.

Variables	Pre-Season	Early-Season	Mid-Season	End-Season
Weeks (n)	4	13	13	13
Training sessions (n)	23	50	46	62
Matches (n)	3	16	17	12
Average total time (min)	9447.1	5652.4	4506.1	4970.4

2.3. Monitoring External Load

2.3.1. GPS Receiver Specifications

All players' activities were recorded in training sessions and matches using SPI HPU, GPSports systems Pty Ltd. (SPI HPU, GPSports, Canberra, Australia). This GPS model's features include: 15Hz position GPS, distance, and speed measurement; accelerometer: 100 Hz, 16 G Tri-Axial-Track impacts, Acc, and Dec, as well as data source body load (BL); Mag: 50 Hz, Tri-Axial; dimensions: smallest device on the market (74 mm × 42 mm × 16 mm); robustness; SPI HPU based on Mining/Industrial Strength Electronics design; water resistance and data transmission: infra-red and weighs 56g. Previously, it has been shown that the GPS unit was tested for having a very high accuracy demonstrated validity and inter-unit reliability [15]. Collecting data during training sessions and matches provided in favorable weather and GPS satellite status.

2.3.2. Data Collection

The GPS monitoring device was turned on prior to the training session or match and set upright in the belt pocket, then 15 min before the training session, the green light (GPS tracking) and red light (heart-rate tracking) were both blinking. Following the session, we collected tracking units from players and put them on the docking station to automatically download into docking memory before removing them from the units to prepare for the next session. The following variables were evaluated in this analysis, according to the Default Zone in the SPI IQ Absolutes: AccZ1 (-2 m/s^2), AccZ2 (2 to 4 m/s^2), AccZ3 (>4 m/s^2), DecZ1 (-2 m/s^2), DecZ2 (-2 to -4 m/s^2), and DecZ3(>-4 m/s^2) [19,23].

2.3.3. Calculate Training Load

In this analysis, weekly acute load (wAL) for each variable was total sessions that were kept on per week. The following variables were obtained: (1) wAL, the accumulated daily number of variables during 1-week; (2) wTM, the relation of wAL by standard deviation (SD) during 1-week; (3) wTS, is the multiplication of wAL by wTM. The weekly average of all zone Acc and Dec in-season cycles was used for other variables determined by form [23–25].

2.4. Statistical Analysis

SPSS was used for statistical methods and computations (version 25.0; IBM SPSS Inc., Chicago, IL, USA). The data was interpreted as a mean and SD. The normality and homogeneity of the data were tested using Shapiro–Wilk and Levene's tests, respectively. After that, inferential tests were run. To examine between-group differences in all dependent derived-GPS variables for the various seasons, an independent sample *T*-test was used. Additionally, Hedge's g effect size (95% confidence interval) was calculated. The Hopkin's thresholds for effect size statistics were used, as follows: ≤0.2, trivial; >0.2, small; >0.6, moderate; >1.2, large; >2.0, very large; and >4.0, extremely large [16]. Significant differences were considered for $p \leq 0.05$. Between week variations were demonstrated as change percentages, and GraphPad Prism software was used to draw the graphs.

3. Results

Figure 1 shows an overall vision of the weekly average TM and TS variations, based on the number of AccZ1 data, and the CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{AccZ1} in week 28 (4.9 ± 1.3) and TS_{AccZ1} occurred in week 37 (1887.3 ± 499.5) for starters, while the highest TM_{AccZ1} in week 11 (4.4 ± 1.8) and TS_{AccZ1} occurred in week 37 (2307.8 ± 698.3) for non-starters. The lowest TM_{AccZ1} happened in week 2 (2.2 ± 0.3) and week 20 (1.4 ± 0.4) for starters and non-starters, respectively, while groups presented the lowest TS_{AccZ1} in week 20 (514.4 ± 261.3) and 15 (379.2 ± 46.3), respectively (Figure 1a).

The highest CV in TM_{Accz1} occurred at week 31 for starters and for non-starters at week 4 and 15. Additionally, the lowest CV in TM_{Accz1} occurred in week 39 for starters and for non-starters occurred in week 16 (Figure 1b), and highest CV in TS_{Accz1} occurred at week 41 for starters and for non-starters at week 5. Additionally, the lowest CV in TS_{Accz1} occurred in week 26 and week 15 for starters and non-starters (Figure 1c).

Figure 2 shows an overall vision of the weekly average TM and TS variations, based on the number of AccZ2 data, and the CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{AccZ2} in week 11 (3.9 ± 1.7) and TS_{AccZ2} occurred in week 37 (545.3 ± 151.6) for starters, while the highest TM_{AccZ2} in week 43 (4 ± 1.6) and TS_{AccZ2} occurred in week 36 (660.5 ± 490.1) for non-starters. The lowest TM_{AccZ2} happened in week 2 (2 ± 0.3) and week 20 (1.6 ± 0.3) for starters and non-starters, while groups presented the lowest TS_{AccZ2} in weeks 20 (135.1 ± 67.3) and 26 (43.7 ± 20.7), respectively (Figure 2a).

The highest CV in TM_{Accz2} occurred at week 22 for starters and for non-starters at week 29. Additionally, the lowest CV in TM_{Accz2} occurred in week 36 for starters and week 5 and week 31 for non-starters (Figure 2b), and highest CV in TS_{AccZ2} occurred at week 10 and week 25 for starters and for non-starters at week 9. Additionally, the lowest CV in TS_{AccZ2} occurred in week 8 and week 17 for starters and non-starters (Figure 2c).

Figure 3 shows an overall vision of the weekly average TM and TS variations, based on the number of AccZ3 data, and CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{AccZ3} in week 42 (3 ± 1.6) and TS_{AccZ3} occurred in week 37 (99.7 ± 75.9) for starters, while the highest TM_{AccZ3} in week 28 (3.3 ± 1), and TS_{AccZ3} occurred in week 37 (118.1 ± 54.8) for non-starters. The lowest TM_{AccZ3} happened in week 34 (1.9 ± 0.3) and week 29 (1.4 ± 1) for starters and non-starters, while groups presented the lowest TS_{AccZ3} in week 26 (starter = 11.5 ± 6.5, non-starter = 4.3 ± 1.9) (Figure 3a).

The highest CV in TM_{AccZ3} occurred at week 12 for starters and week 21 for non-starters. Additionally, the lowest CV in TM_{AccZ3} occurred in week 14 and week 29 for starters and non-starters (Figure 3b), and highest CV in TS_{AccZ3} occurred at week 37 for starters and for non-starters at week 25. Additionally, the lowest CV in TS_{AccZ3} occurred in week 21 for starters and non-starters (Figure 3c).

Figure 4 shows an overall vision of the weekly average TM and TS variations, based on the number of DecZ1 data, and the CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{DecZ1} in week 11 (4 ± 1.4) and TS_{DecZ1} occurred in week 36 (1614.4 ± 468.2) for starters, and the highest TM_{DecZ1} in week 11 (4.7 ± 2.3), and TS_{DecZ1} occurred in week

37 (1361.8 ± 355.2) for non-starters. The lowest TM_{DecZ1} happened in week 2 (1.9 ± 0.3) and week 20 (1.6 ± 0.9) for starters and non-starters, while groups presented the lowest TS_{DecZ1} in week 15 (247.1 ± 110.8) and week 29 (74.3 ± 6.5), respectively (Figure 4a).

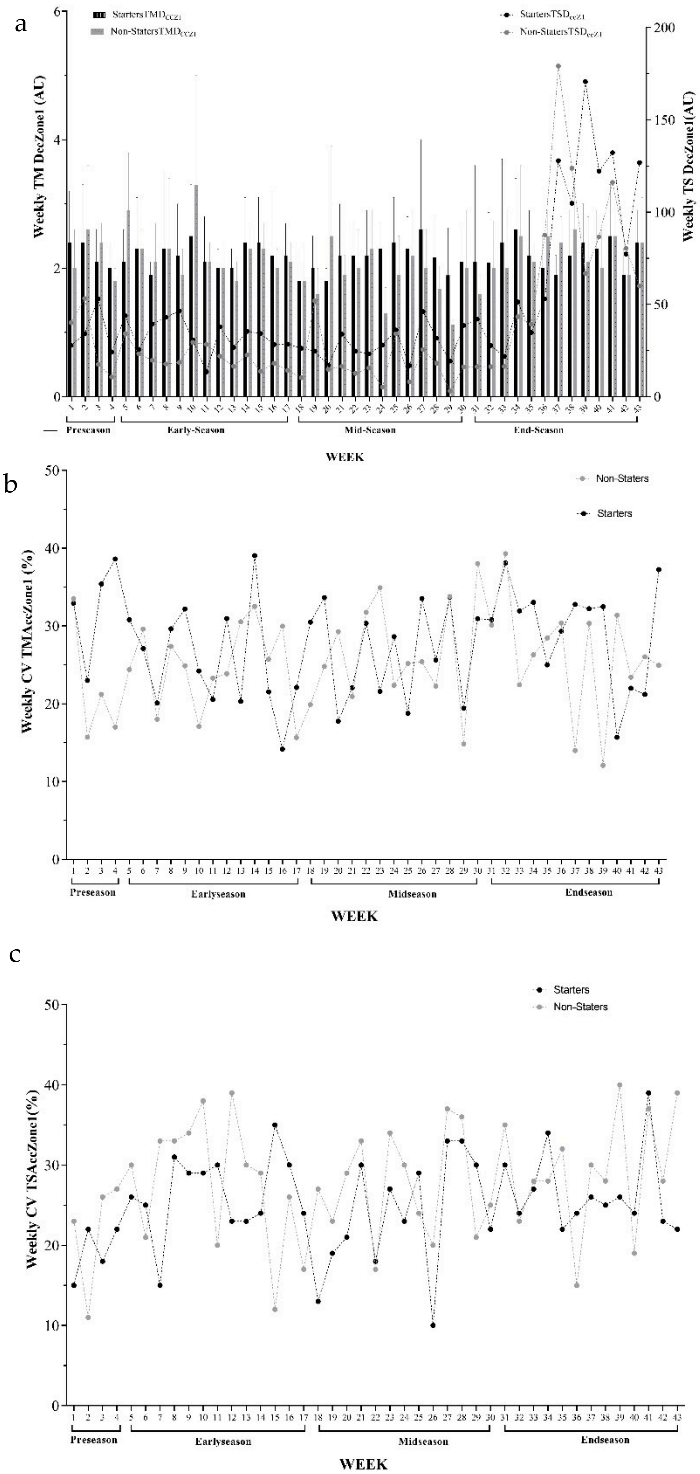

Figure 1. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on (**a**) number of accelerations at zone 1 (AccZ1), (**b**) coefficient of variation (CV) at TM_{AccZ1}, (**c**) coefficient of variation (CV) at TS_{Accz1}.

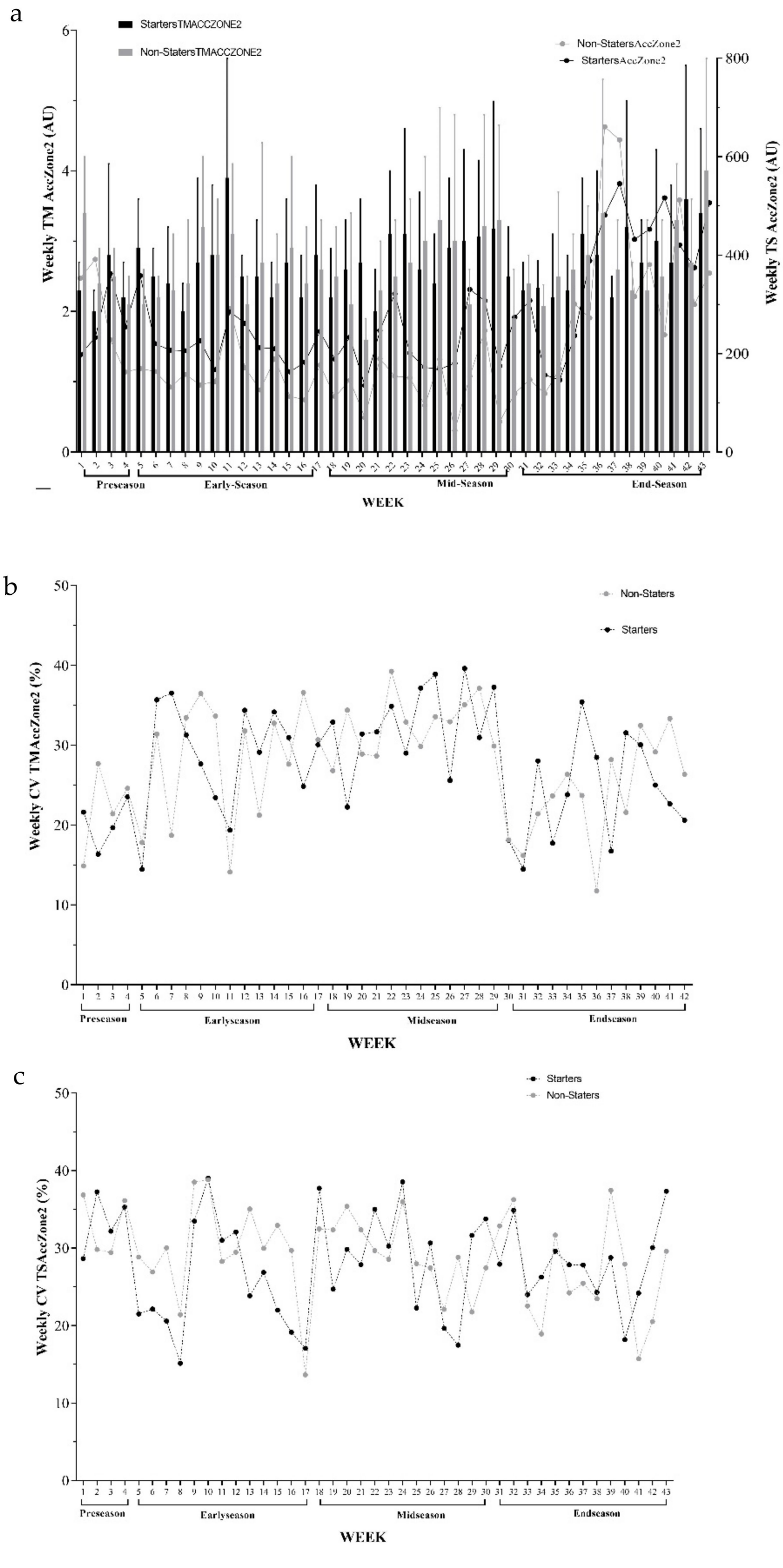

Figure 2. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on (**a**) number of accelerations at zone 2 (AccZ2), (**b**) coefficient of variation (CV) at TM_{AccZ2}, (**c**) coefficient of variation (CV) at TS_{Accz2}.

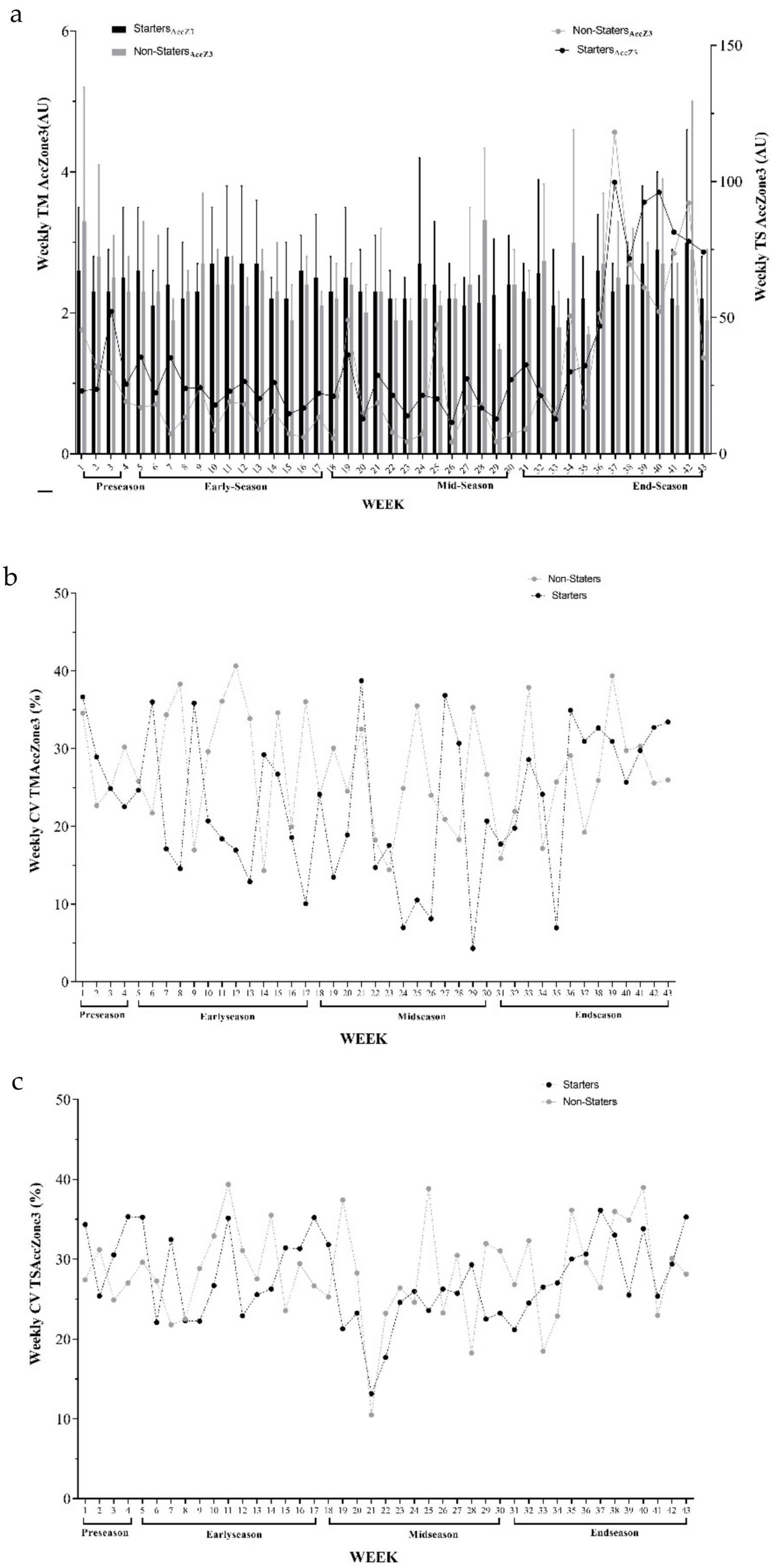

Figure 3. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on, (**a**) number of accelerations at zone 3 (AccZ3), (**b**) coefficient of variation (CV) at TM_{AccZ3}, (**c**) coefficient of variation (CV) at TS_{Accz3}.

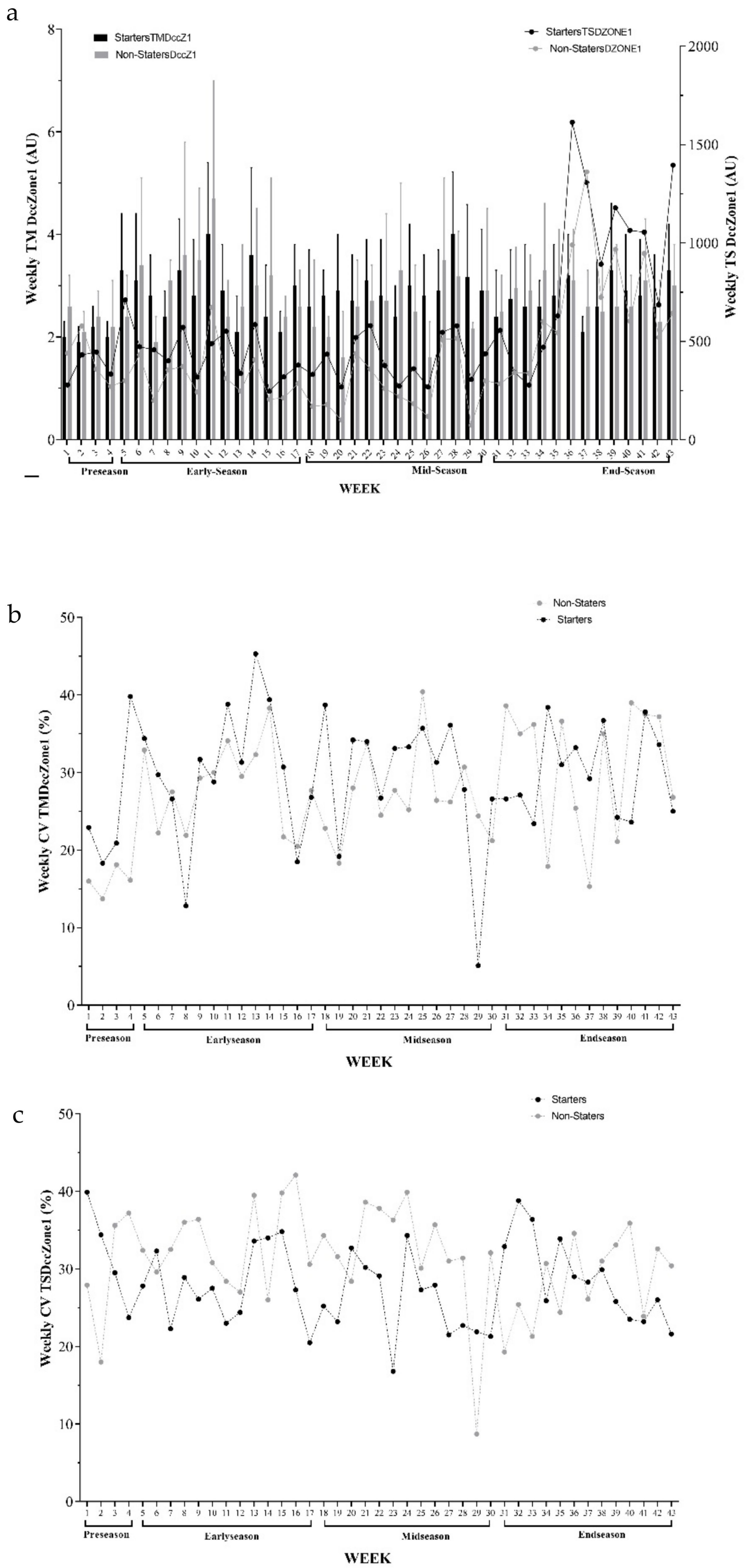

Figure 4. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on, (**a**) number of decelerations at zone 1 (DecZ1), (**b**) coefficient of variation (CV) at TM_{DecZ1}, (**c**) coefficient of variation (CV) at TS $_{DecZ1}$.

The highest CV in TM_{DecZ1} occurred at week 3 for starters and for non-starters at week 31. Additionally, the lowest CV in TM_{DecZ1} occurred in week 37 and week 29 for starters and non-starters, respectively (Figure 4b), and highest CV in TS_{DecZ1} occurred at week 32 for starters and for non-starters at week 16. Additionally, the lowest CV in TS_{DecZ1} occurred in week 23 and week 29 for starters and non-starters, respectively (Figure 4c).

Figure 5 shows an overall vision of the weekly average TM and TS variations, based on the number of DecZ2 data, and the CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{DecZ2} in week 38 (3.4 $\pm$ 1.8) and TS_{DecZ2} occurred in week 43 (454.5 $\pm$ 289) for starters, while the highest TM_{DecZ2} in week 29 (5.2 $\pm$ 1.6), and TS_{DecZ2} occurred in week 36 (520 $\pm$ 223.8) for non-starters. The lowest TM_{DecZ2} happened in week 33 (1.9 $\pm$ 0.3) and week 20 (1.5 $\pm$ 0.3) for starters and non-starters, while groups presented the lowest TS_{DecZ2} in week 33 (56.1 $\pm$ 33.2) and week 26 (15.8 $\pm$ 12.1), respectively (Figure 5a).

The highest CV in TM_{DecZ2} occurred at week 20 for starters and for non-starters at week 3. Additionally, the lowest CV in TM_{DecZ2} occurred in week 8 and week 35 for starters and non-starters (Figure 5b), and highest CV in TS_{DecZ2} occurred at week 35 for starters and week 16 for non-starters. Additionally, the lowest CV in TS_{DecZ2} occurred in week 25, 26, and 28 and week 8 for starters non-starters, respectively (Figure 5c).

Figure 6 shows an overall vision of the weekly average TM and TS variations, based on the number of DecZ3 data, and the CV of TM and TS across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. Overall, the highest TM_{DecZ3} in week 34 (2.6 $\pm$ 0.8) and TS_{DecZ3} occurred in week 39 (170.7 $\pm$ 68.6) for starters, and the highest TM_{DecZ3} in week 10 (3.3 $\pm$ 1.7), and TS_{DecZ3} occurred in week 37 (179.2 $\pm$ 74.1) for non-starters. The lowest TM_{DecZ3} happened in week 20 (1.8 $\pm$ 0.2) and week 29 (1.1 $\pm$ 0.1) for starters and non-starters, respectively, while groups presented the lowest TS_{DecZ3} in week 11 (13.4 $\pm$ 8.4) and week 29 (3.1 $\pm$ 1.9), respectively (Figure 6a).

The highest CV in TM_{DecZ3} occurred at week 29 for starters and for non-starters at week 2. Additionally, the lowest CV in TM_{DecZ3} occurred in week 20 and week 29 for starters and non-starters (Figure 6b), and highest CV in TS_{DecZ3} occurred at week 17 for starters and for non-starters at week 40. Additionally, the lowest CV in TS_{DecZ3} occurred in week 25 and week 16 for starters and non-starters, respectively (Figure 6c).

Figure 7 shows the change percentages (PC) changes for TM and TS in the AccZ1, AccZ2, and AccZ3 zones across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. The highest CP in TM_{Accz1} occurred at week 19 (61%) for starters and for non-starters at week 21 (109%). Additionally, the lowest CP in TM_{Accz1} occurred in week 4 (0%) for starters and non-starters (Figure 7a), the highest CP in TS_{Accz1} occurred at week 5 (91%) for starters and for non-starters at week 21 (484%). The lowest CP in TS_{Accz1} occurred in week 3 (1%) and week 41 (4%) for starters and non-starters, respectively (Figure 7b).

The highest CP in TM_{Accz2} occurred at week 22 (55%) for starters and for non-starters at week 28 (53%). The lowest CP in TM_{Accz2} occurred in week 28 (1%) and week 5 ($-$1%) for starters and non-starters, respectively (Figure 7c). The highest CP in TS_{AccZ2} occurred at week 27 for starters (83%) and for non-starters (253%). The lowest CP in TS_{AccZ2} occurred in week 14 ($-$1%) and week 22 ($-$2%) for starters and non-starters, respectively (Figure 7d).

The highest CP in TM_{AccZ3} occurred at week 42 (32%) for starters and for non-starters at week 34 (69%). The lowest CP in TM_{AccZ3} occurred in week 28 (1%) and week 11 (2%) for starters and non-starters (Figure 7e). The highest CP in TS_{AccZ3} occurred at week 27 (140%) for starters and for non-starters at week 19 (770%). The lowest CP in TS_{AccZ3} occurred in week 2 (3%) and week 12 ($-$5%) for starters and non-starters, respectively (Figure 7f).

Figure 8 shows the PC changes for TM and TS in the DecZ1, DecZ2, and DecZ3, zones across the full-season and its different periods (pre-, early-, mid-, and end-season) for starters and non-starters players. The highest CP in TM_{DecZ1} occurred at week 5 (70%) for starters and for non-starters at week 27 (112%). The lowest CP in TM_{DecZ1} occurred in week 34 and week 40 (0%) for starters and non-starters, respectively (Figure 8a). The highest CP in TS_{DecZ1} occurred at week 36 (156%) for starters and for non-starters at week 21 (334%). The lowest CP in TS_{DecZ1} occurred in week 41 ($-$1%) and week 28 (1%) for starters and non-starters (Figure 8b).

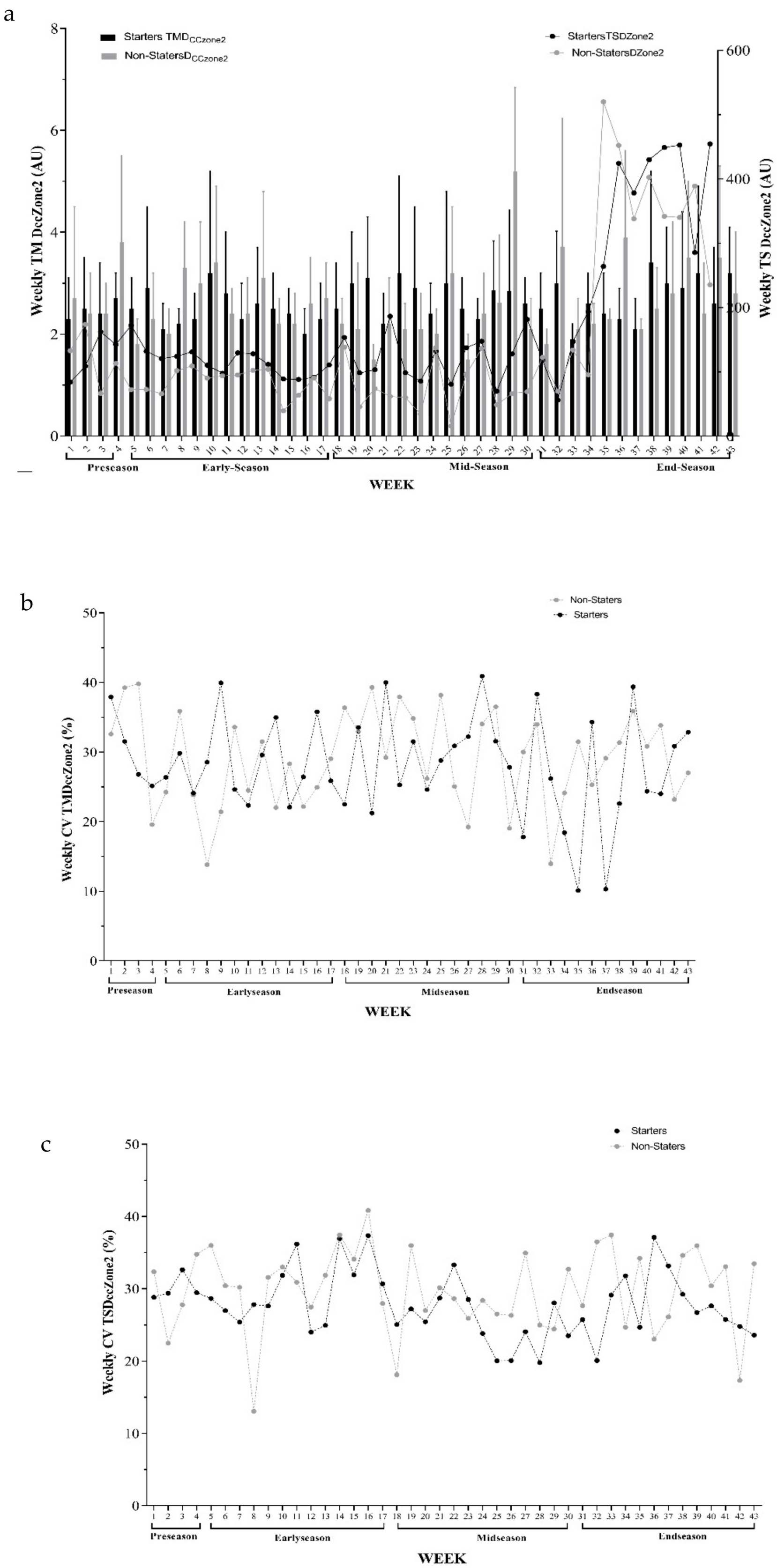

Figure 5. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on (**a**) number of decelerations at zone 2 (DecZ2), (**b**) coefficient of variation (CV) at TM_{DecZ2}, (**c**) coefficient of variation (CV) at TS $_{DecZ2}$.

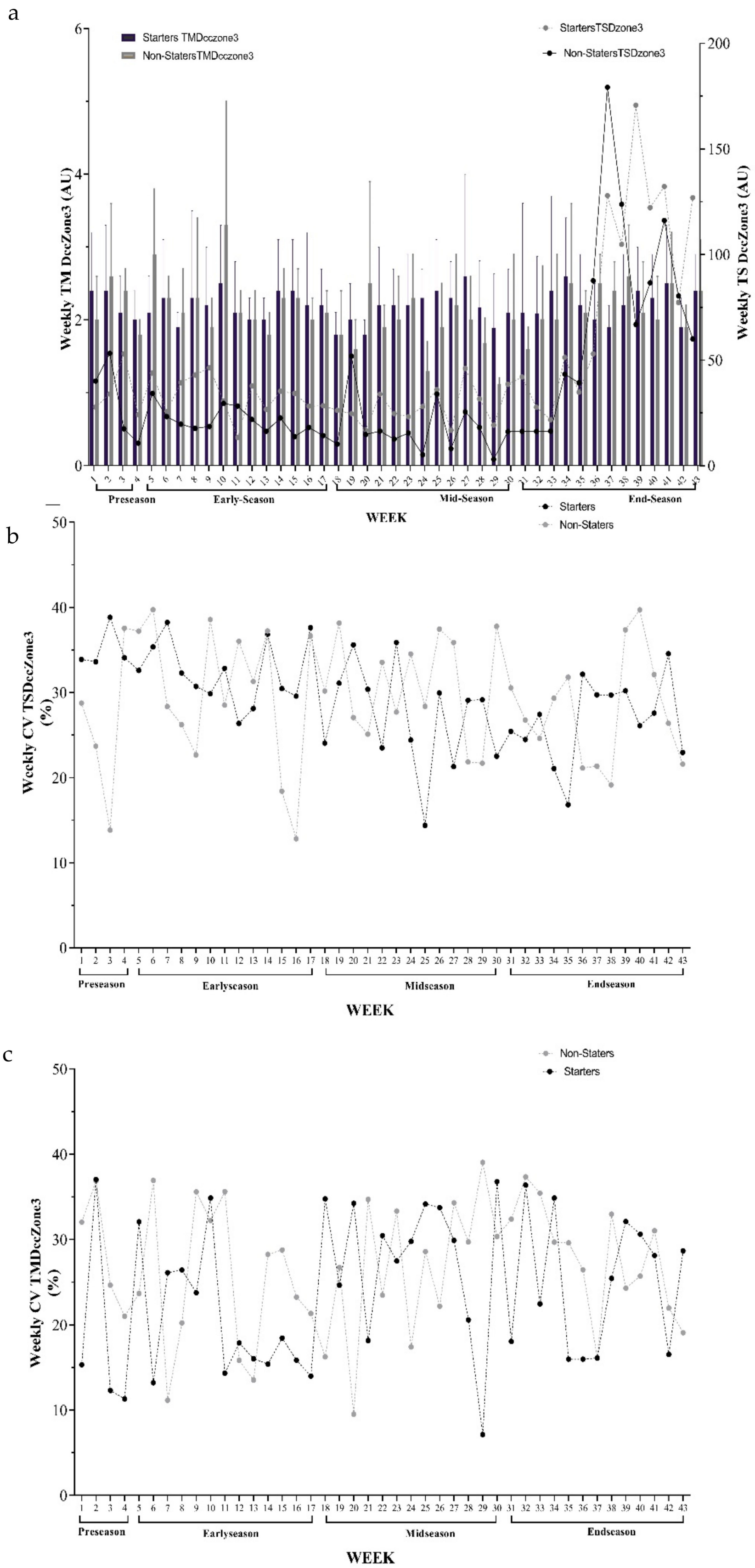

Figure 6. Descriptive statistics of weekly average for training monotony (TM) and training strain (TS) and their variations across the full-season based on, (**a**) number of decelerations at zone 3 (DecZ3), (**b**) coefficient of variation (CV) at TM_{DecZ3}, (**c**) coefficient of variation (CV) at TS $_{DecZ3}$.

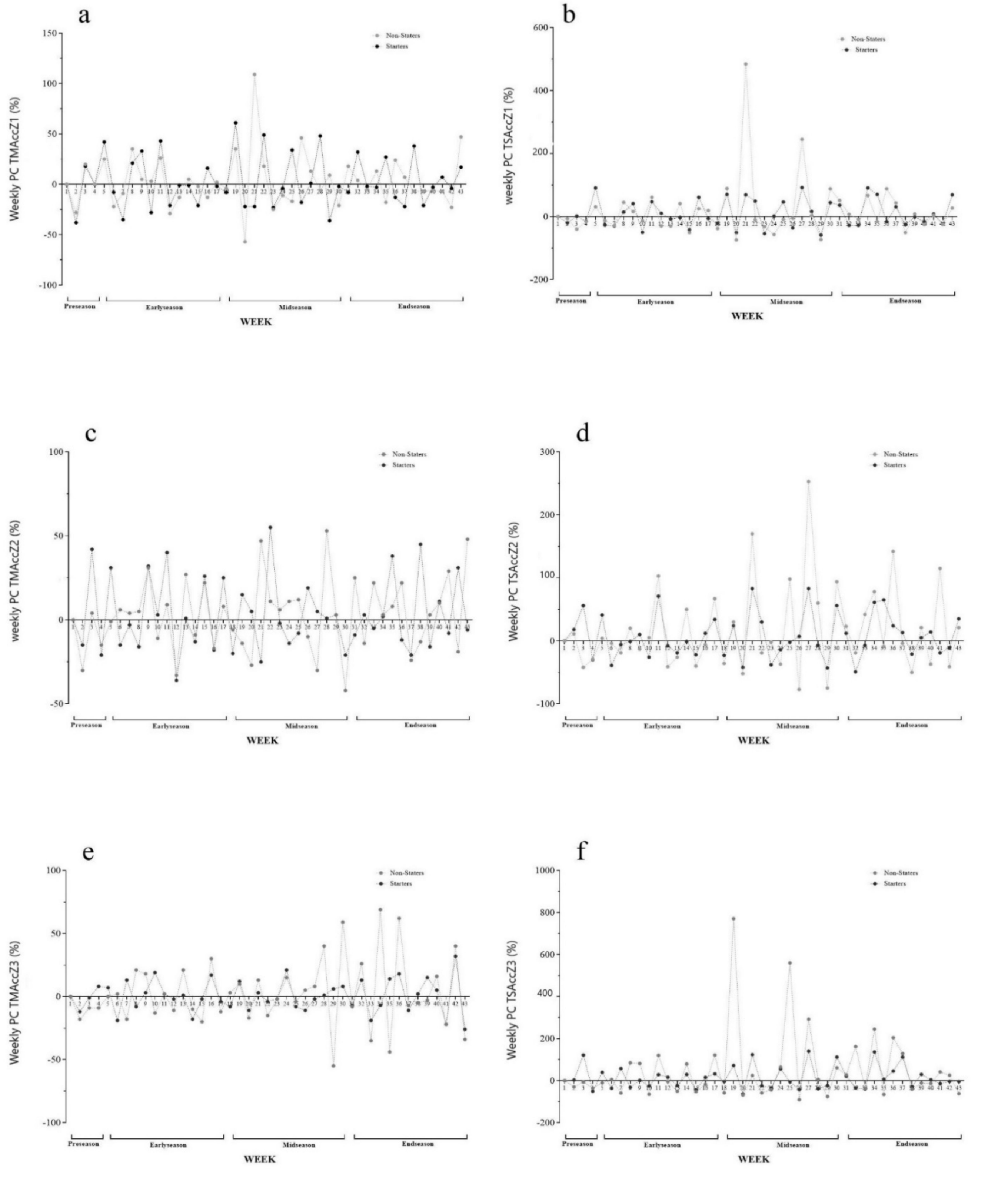

Figure 7. Weekly fluctuations for change percentages (CP) at (**a**) TM_{AccZ1}, (**b**) TS_{AccZ1}, (**c**) TM_{AccZ2}, (**d**) TS_{AccZ2}, (**e**) TM_{AccZ3}, (**f**) TS_{AccZ3}. TM: Training monotony; Acc: Acceleration; Z; zone; TS: Training strain.

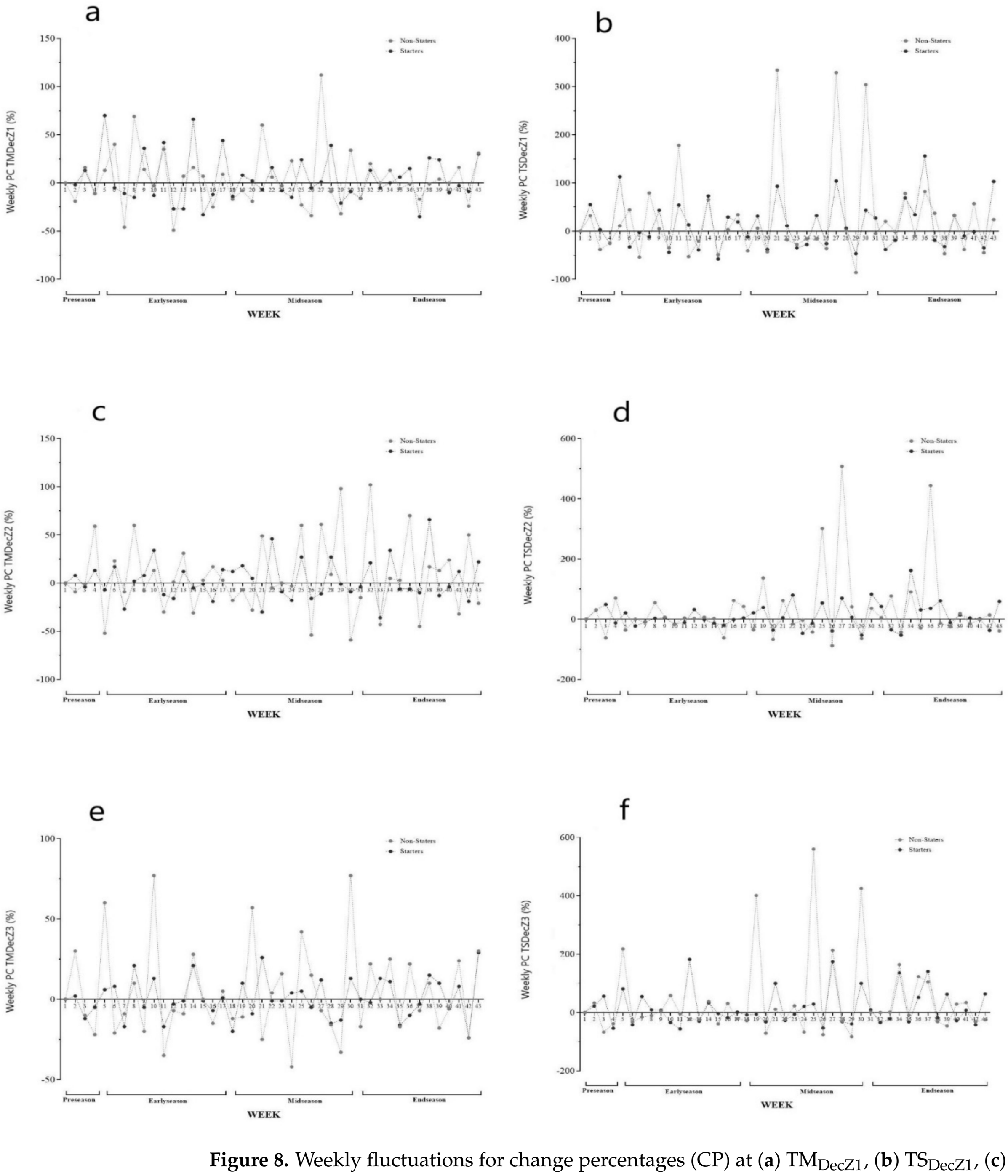

Figure 8. Weekly fluctuations for change percentages (CP) at (**a**) TM_{DecZ1}, (**b**) TS_{DecZ1}, (**c**) TM_{DecZ2}, (**d**) TS_{DecZ2}, (**e**) TM_{DecZ3}, (**f**) $TS_{DEcZ3.}$ TM: Training monotony; Dec: Deceleration; Z; zone; TS: Training strain.

The highest CP in TM_{DecZ2} occurred at week 38 (66%) for starters and for non-starters at week 32 (102%). The lowest CP in TM_{DecZ2} occurred in week 15 (−1%) and week 23 (0%) for starters and non-starters, respectively (Figure 8c). The highest CP in TS_{DecZ2} occurred at week 34 (162%) for starters and for non-starters at week 27 (508%). The lowest CP in TS_{DecZ2} occurred in week 41 (1%) and week 6 (0%) for starters and non-starters, respectively (Figure 8d).

The highest CP in TM_{DecZ3} occurred at week 21 (26%) for starters and for non-starters at week 30 (77%). The lowest CP in TM_{DecZ3} occurred in week 31 and week 16 (0%) for starters and non-starters, respectively (Figure 8e). The highest CP in TS_{DecZ3} occurred at week 27 (174%) for starters and for non-starters at week 25 (560%). The lowest CP in TS_{DecZ3} occurred in week 17 and week 33 (1%) for starters and non-starters, respectively (Figure 8f).

Table 2 shows the between-group comparisons on weekly average TM_{AccZ1}, TS_{AccZ1}, TM_{AccZ2}, TS_{AccZ2}, TM_{AccZ3}, and TS_{AccZ3} for the different periods of the season. Coincidently, results revealed moderate to very large significant greater weekly average TM_{AccZ1}, TS_{AccZ1}, TM_{AccZ2}, TS_{AccZ2}, TM_{AccZ3}, and TS_{AccZ3} of starters compared to non-starters during early-season (TS_{AccZ1}: $p = 0.003$, $g = 1.50$; TS_{AccZ2}: $p = 0.008$, $g = 1.32$; and TS_{AccZ3}: $p = 0.006$, $g = 1.23$) and mid-season (TS_{AccZ1}: $p = 0.0012$, $g = 1.23$; TS_{AccZ2}: $p \leq 0.001$, $g = 1.90$).

Table 3 shows the between-group comparisons on weekly average TM_{DecZ1}, TS_{DecZ1}, TM_{DecZ2}, TS_{DecZ2}, TM_{DecZ3}, and TS_{DecZ3} for the different periods of the season. Similar to the outcomes obtained for parameters based on Acc, moderate to nearly perfect significant greater weekly average TM_{DecZ1}, TS_{DecZ1}, TM_{DecZ2}, TS_{DecZ2}, TM_{DecZ3}, and TS_{DecZ3} were found in starters compared to non-starters during pre-season (TM_{AccZ1}: $p = 0.003$, $g = -1.31$); early-season (TS_{AccZ1}: $p = 0.005$, $g = 1.41$; TS_{AccZ2}: $p = 0.002$, $g = 1.60$; and TS_{AccZ3}: $p = 0.011$, $g = 1.25$); mid-season (TM_{AccZ1}: $p = 0.036$, $g = 0.92$; TS_{AccZ1}: $p \leq 0.001$, $g = 2.24$; TM_{AccZ2}: $p = 0.001$, $g = 1.51$; TS_{AccZ2}: $p = 0.035$, $g = 1.00$; and TM_{AccZ3}: $p = 0.026$, $g = 0.95$); and end-season (TS_{AccZ1}: $p = 0.009$, $g = 1.32$).

Table 2. Differences between starters and non-starters on training monotony and training strain based on acceleration derived-GPS variables in the full-season and its different periods.

Workload Parameters	Season Period	Group		%Difference (Non-Starters–Starters)	*p*	Hedge's *g* (95% CI) (Non-Starters–Starters)
		Starters	Non-Starters			
TM_{AccZ1} (AU)	Pre-season	2.7 (0.6)	2.7 (0.3)	<0.001 (−0.4 to 0.4)	0.447	<0.001 (−0.9 to 0.9)
	Early-Season	2.9 (0.2)	3.1 (0.4)	−0.2 (−0.5 to 0.1)	0.400	−0.6 (−1.5 to 0.3)
	Mid-Season	2.9 (0.1)	2.7 (0.4)	0.2 (−1 to 0.5)	0.168	0.6 (−0.2 to 1.6)
	End-Season	3.0 (0.2)	3.1 (0.3)	−0.1 (−0.3 to 0.1)	0.641	−0.3 (−1.2 to 0.5)
TS_{AccZ1} (AU)	Pre-season	931.4 (223.2)	937.1 (155.6)	−5.7 (−194.1 to 182.7)	0.950	−0.02 (−0.9 to 0.8)
	Early-Season	906.2 (146.8)	700.1 (109.8)	206.1 (79.4 to 332.8)	**0.003** *	1.5 (0.5 to 2.5)
	Mid-Season	816.9 (133.5)	611.1 (183.9)	205.8 (51.4 to 360.15)	**0.012** *	1.2 (0.2 to 2.2)
	End-Season	1233.4 (282.4)	1085.5 (203.0)	147.9 (−92.7 to 388.5)	0.212	0.5 (−0.3 to 1.5)
TM_{AccZ2} (AU)	Pre-season	2.3 (0.4)	2.6 (0.2)	−0.3 (−0.6 to 0)	0.072	−0.9 (−1.8 to 0)
	Early-Season	2.6 (0.3)	2.6 (0.4)	<0.001 (−0.3 to 0.3)	0.842	<0.001 (−0.9 to 0.9)
	Mid-Season	2.7 (0.2)	2.4 (0.4)	0.3 (−≤0.001 to 0.6)	0.074	0.9 (0 to 1.8)
	End-Season	2.7 (0.3)	2.7 (0.2)	<0.001 (−0.2 to 0.2)	0.981	<0.001 (−0.9 to 0.9)
TS_{AccZ2} (AU)	Pre-season	261.9 (75.7)	285.0 (68.8)	−23.1 (−93.4 to 47.2)	0.497	−0.3 (−1.2 to 0.6)
	Early-Season	225.7 (40.5)	166.0 (45.6)	59.7 (18.5 to 101.3)	**0.008** *	1.3 (0.3 to 2.3)
	Mid-Season	225.8 (45.9)	144.7 (34.1)	81.1 (41.5 to 120.6)	**<0.001** *	1.9 (0.8 to 2.9)
	End-Season	379.0 (95.6)	344.7 (37.9)	34.3 (−37.6 to 106.2)	0.447	0.4 (−0.4 to 1.3)
TM_{AccZ3} (AU)	Pre-season	2.4 (0.4)	2.6 (0.7)	−0.2 (−0.7 to 0.3)	0.549	−0.3 (−1.2 to 0.5)
	Early-Season	2.4 (0.2)	2.3 (0.1)	0.1 (≤0.001 to 0.2)	0.103	0.6 (−0.3 to 1.5)
	Mid-Season	2.3 (0.2)	2.2 (0.3)	0.1 (−0.1 to 0.3)	0.215	0.3 (−0.5 to 1.2)
	End-Season	2.4 (0.2)	2.4 (0.4)	<0.001 (−0.3 to 0.3)	0.853	<0.001 (−0.9 to 0.9)
TS_{AccZ3} (AU)	Pre-season	33.1 (12.5)	29.0 (15.3)	4.1 (−9.3 to 17.5)	0.522	0.2 (−0.6 to 1.1)
	Early-Season	23.4 (7.9)	15.0 (4.5)	8.4 (2.1 to 14.7)	**0.006** *	1.2 (0.2 to 2.2)
	Mid-Season	20.9 (6.3)	17.6 (16.0)	3.3 (−8.2 to 14.8)	0.113	0.2 (−0.6 to 1.1)
	End-Season	59.3 (22.8)	50.4 (12.8)	8.9 (−9.3 to 27.1)	0.497	0.4 (−0.4 to 1.3)

Abbreviations: AU, arbitrary units; TM_{AccZ1}, weekly average training monotony based on number of accelerations at zone 1 (<2 $m \cdot s^{-2}$); TS_{AccZ1}, weekly average training strain based on number of accelerations at zone 1 (<2 $m \cdot s^{-2}$); TM_{AccZ2}, weekly average training monotony based on number of accelerations at zone 2 (2 to 4 $m \cdot s^{-2}$); TS_{AccZ2}, weekly average training strain based on number of accelerations at zone 2 (2 to 4 $m \cdot s^{-2}$); TM_{AccZ3}, weekly average training monotony based on number of accelerations at zone 3 (>4 $m \cdot s^{-2}$); TS_{AccZ3}, weekly average training strain based on number of accelerations at zone 3 (>4 $m \cdot s^{-2}$); *p*, *p*-value at alpha level 0.05; Hedge's *g* (95% CI), Hedge's *g* effect size magnitude with 95% confidence interval. * Significant differences ($p \leq 0.05$) are highlighted in bold.

Table 3. Differences between starters and non-starters on TM and TS based on deceleration derived-GPS variables in the full-season and its different periods.

Workload Parameters	Season Period	Group		%Difference (Non-Starters–Starters)	p	Hedge's g (95% CI) (Non-Starters–Starters)
		Starters	Non-Starters			
TM_{DecZ1} (AU)	Pre-season	2.0 (0.1)	2.3 (0.3)	−0.3 (−0.5 to −0.1)	**0.003** *	−1.3 (−2.3 to −0.3)
	Early-Season	2.9 (0.2)	3.0 (0.4)	−0.1 (−0.4 to 0.2)	0.506	−0.3 (−1.2 to 0.6)
	Mid-Season	2.9 (0.2)	2.6 (0.4)	0.3 (≤0.001 to 0.6)	**0.036** *	0.9 (≤0.001 to 1.8)
	End-Season	2.8 (0.4)	2.9 (0.2)	−0.100 (−0.4 to 0.2)	0.643	−0.3 (−1.2 to 0.6)
TS_{DecZ1} (AU)	Pre-season	371.3 (52.6)	412.2 (68.2)	−40.9 (−99.4 to 17.7)	0.278	−0.6 (−1.5 to 0.2)
	Early-Season	449.3 (79.9)	339.7 (67.3)	109.6 (37.6 to 181.5)	**0.005** *	1.4 (0.4 to 2.4)
	Mid-Season	406.9 (58.0)	295.8 (31.2)	111.1 (65.2 to 156.9)	**<0.001** *	2.2 (1.1 to 3.4)
	End-Season	889.1 (123.2)	697 (154.2)	192.1 (57.6 to 326.5)	**0.009** *	1.3 (0.3 to 2.3)
TM_{DecZ2} (AU)	Pre-season	2.5 (0.5)	2.8 (0.8)	−0.3 (−0.9 to 0.3)	0.243	−0.4 (−1.3 to 0.4)
	Early-Season	2.5 (0.5)	2.6 (0.3)	−0.1 (−0.5 to 0.3)	0.278	−0.2 (−1.1 to 0.6)
	Mid-Season	2.7 (0.2)	2.3 (0.3)	0.4 (0.1 to 0.6)	**0.001** *	1.5 (0.5 to 2.5)
	End-Season	2.7 (0.4)	2.8 (0.5)	−0.1 (−0.5 to 0.3)	0.831	−0.2 (−1.1 to 0.7)
TS_{DecZ2} (AU)	Pre-season	124.4 (25.8)	120.3 (41.4)	4.1 (−28.9 to 37.1)	0.794	0.1 (−0.7 to 1)
	Early-Season	117.5 (19.2)	88.0 (15.5)	29.5 (12.4 to 46.5)	**0.002** *	1.6 (0.5 to 2.6)
	Mid-Season	117.9 (26.0)	83.1 (39.7)	34.8 (2.6 to 66.9)	**0.035** *	1 (0 to 1.9)
	End-Season	298.4 (70.2)	269.6 (40.0)	28.8 (−27.4 to 85)	0.295	0.4 (−0.4 to 1.3)
TM_{DecZ3} (AU)	Pre-season	2.2 (0.4)	2.1 (0.4)	0.1 (−0.2 to 0.4)	0.828	0.2 (−0.6 to 1.1)
	Early-Season	2.2 (0.2)	2.3 (0.3)	−0.1 (−0.3 to 0.1)	0.651	−0.3 (−1.2 to0.5)
	Mid-Season	2.1 (0.3)	1.8 (0.3)	0.3 (≤0.001 to 0.5)	**0.026** *	0.9 (≤0.001 to 1.9)
	End-Season	2.2 (0.3)	2.2 (0.2)	<0.001 (−0.2 to 0.2)	0.791	<0.001 (−0.9 to 0.9)
TS_{DecZ3} (AU)	Pre-season	33.3 (24.5)	29.9 (11.6)	3.4 (−15.5 to 22.3)	0.661	0.1 (−0.7 to 1)
	Early-Season	33.5 (10.7)	21.9 (6.1)	11.6 (3 to 20.1)	**0.011** *	1.2 (0.2 to 2.2)
	Mid-Season	28.2 (9.8)	24.7 (21.2)	3.5 (−12.2 to 19.2)	0.113	0.2 (−0.7 to 1.1)
	End-Season	85.5 (20.9)	73.5 (18.8)	12 (−7.3 to 31.3)	0.198	0.5 (−0.3 to 1.5)

Abbreviations: AU, arbitrary units; TM_{DecZ1}, weekly average training monotony based on number of decelerations at zone 1 (>−2 m·s^{-2}); TS_{DecZ1}, weekly average training strain based on number of deceleration at zone 1 (>−2 m·s^{-2}); TM_{DecZ2}, weekly average training monotony based on number of deceleration at zone 2 (−2 to −4 m·s^{-2}); TS_{AccZ2}, weekly average training strain based on number of accelerations at zone 2 (2 to 4 m·s^{-2}); TM_{DecZ3}, weekly average training monotony based on number of decelerations at zone 3 (<−4 m·s^{-2}); TS_{DecZ3}, weekly average training strain based on number of decelerations at zone 3 (<−4 m·s^{-2}); p, p-value at alpha level 0.05; Hedge's g (95% CI), Hedge's g effect size magnitude with 95% confidence interval. * Significant differences ($p \leq 0.05$) are highlighted in bold.

4. Discussion

The main goal of this study was to compare the TM and TS of starters and non-starters across the full-season. Our hypothesis was that the starter players would tolerate higher TM and TS in all four periods of the season than non-starter players. The study confirmed some of our hypotheses and rejected others so that our hypothesis was confirmed in early- and mid-season, while it was rejected in the pre- and end-season. The major finding of this study was the high values of TS in pre- and end-season, which did not differ significantly between the starter and non-starter groups, and also the low TS in the non-starter group in early- and mid-season, which showed a significant difference in these periods between the two groups.

The objectives of the study were to describe the weekly averages for TM and TS and their variations across the full-season based on the number of Acc and Dec, as well as to examine the differences between starters and non-starters players on weekly average TM and TS for the pre- and in-season periods based on the number of Acc and Dec. The first goal of the research is shown in the diagrams (Figures 1–6) and shows the major changes in workloads between the starter and non-starters.

In connection with the changes shown in Figures 1–6, it can be seen that the highest TS in Acc and Dec in all areas were observed during the end-season. A reason can be the fatigue of the players due to the long season, and the team's presence in three important and difficult tournaments (Premier League, Iran National Cup, and Asian Champions League). A similar increase in TS in starter and non-starter players at this time could be due to the replacement of starter players in tight matches with non-starter players, due to the fatigue of the starter players as a result of fatigue from too many matches. In the exercise science, fatigue is associated with a decrement in the ability of the muscles to produce force. Fatigue reduces muscle strength as well as player concentration and, therefore, it reduces athletes' overall performance. This, if not accompanied by sufficient recovery time, will further reduce the athlete's performance [26]. This happens to the most used starter players when football matches are tight, so the coach has to use more replacement players. The highest TS levels were observed for the starter group at Accz1, Accz2, Accz3, and for the non-starter group at Decz3, Accz1, Accz3, Decz1 at week 37. Additionally, the highest TS levels were recorded for Decz2 and Accz2 in the non-starter group, while in the starter group the Decz1were found at week 36, Decz2 at week 43, and Decz3 at week 39. In addition, according to the graphs, it is shown that TS is higher in the pre-season than in the early- and mid-season. These findings are consistent with the results of some research, which means that pre-season training sessions are focused on improving the physical condition of the players with a higher training pressure [7,15,27–29]. The lowest TS values were observed in Accz1 for the non-starter group at week 20 and in the starter group at week 15, in Accz2 for the non-starter group at week 26 and for the starter group at week 20, in Accz3 for both the starter and non-starter groups at week 26. Additionally, the lowest TS in Decz1 for the non-starter group at week 29 and for the starter group at week 15, in Decz2 for the non-starter group at week 26 and for the starter group at week 33, and in Decz3 for the non-starter group at week 29 and for the starter group in week 11.

The highest level of TM was recorded for the non-starter group in Accz1, Decz1, Decz3 and in the starter group in Accz2, Decz1 at 11 weeks of training. Most TM was observed for Accz3 in the non-starter group at week 1 and the starter group at week 42, for Decz3 in the non-starter group at week 10 and the starter group at week 34, for Accz1 in the starter group at week 28, for Accz2 in the group non-starter at week 43 and Decz2 in the non-starter group at week 29 and in the starter group at week 38. Additionally, according to Figures 1–6, all of the highest CVs occurred in the early- and mid-season, and the CV in the non-starter group was always higher than the non-starter group. In addition, according to Figures 7 and 8, non-starters in CP also had more fluctuations in all zones and had the most CPs in all zones.

While at the pre- and end-season the results can easily be explained by the similarities between starter and non-starter in the weeks with higher TM and TS, it is not clear why it fluctuates during the season and there is a W-shaped in the diagram. A number of factors, such as match position, match result, opponent quality, tactics system, and training program, can affect these results [4]. Contextual factors such as tactical formation and suspension of a match can affect the overall workload during a match, and further into the previous or next training session. Evidence shows that players competing in some match formations (3–5-2) can cover more total distance, higher speeds, and perform more Acc/Dec compared to other formations [15,29].

Few studies have examined TM and TS for monitoring training in different teams [6,7,15,30]. Nobari et al. [15] and Lazarus et al. [30] concluded that TM and TS have many changes in different weeks, and that it is difficult to understand the changes in these variables. As in the present study, Delecroix et al. [6] showed that regular workload is a very important factor for protection against non-collision injuries, while high TS can increase risk factors during training and competition if it is maintained for 4 weeks. As mentioned earlier, TS in our study showed oscillating and W-shaped behavior, which will increase the likelihood of increased risk factors and non-contact injuries.

Although the comparison between the starter and non-starter groups is statistically different in several zones of Acc and Dec, at the beginning and end of the season the increase in TS and TM was the same in both groups. As mentioned earlier, the reason for this increase at the pre-season was probably due to the increase in workload and physical capacity in the pre-season preparation phase [15,16]. The reason for the similar increase in TM and TS at the end-season was the increase in the fatigue of the starter players, due to participating in various tournaments, the pressure of the match, and replacing the starter players with non-starter players during the match. The first part of the above findings was consistent with the findings of Nobari et al. (2021), but the second part was inconsistent with their findings. Nobari et al. showed that at the end of the season there was a significant difference between the starter group and the non-starter group, citing a focus on the starter players to play better [15]. Of course, it is necessary to mention that before the end-season, in the current research, the match and training of the teams were closed for two months due to the outbreak of coronavirus, and the high TS at the end-season was probably due to the players' physical decline at this time.

Regarding the second aim, it should be kept in mind that soccer has changed a lot compared to previous years, and has become a dynamic game in which players are changing positions to perform different tactical tasks and need to run fast in different situations [15,31]. To perform better in various tactical roles, players must be able to perform intense Acc and Dec actions repeatedly. High-intensity Acc and Dec are two very important metrics of external load. Both have distinctive and disparate internal physiological and mechanical loading demands on players [32]. High Acc and Dec increase metabolic demand, and on the other hand, high external load along with severe Dec increases the pressure on soft tissues and causes non-collision injuries [33]. That is why the frequency of Acc and Dec is associated with decrements in neuromuscular performance after the matches [34]. In general, the results of the present study show that in early- and mid-season, the starter and non-starter groups are significantly different in TS and TM, and the starter group performs more Acc and Dec. This finding reinforces that the workload for non-starter players during the season is not enough to improve these players during the season. For this reason, the coaches and training staff of the teams, when preparing non-starter players, should consider a different training program from the starter players, and provide the necessary overload to these players to progress. However, Anderson et al. [35], as well as Nobari et al. [15], showed that during the season, the non-starter and starter groups have significant differences in running distance, sprint, TS, and TM. In the present study, it was shown that these two groups have significant differences in mid-season and early-season in TS and TM Acc and Dec. These results indicate that workload monitoring during the season should be based on player position, tactical tasks, being a starter or non-starter, and in addition to team training, specific exercises should be considered for each group.

There were limitations to the present study that need to be addressed in future studies. The small sample size limits the number of players and teams analyzed for the present study, which has been frequently reported in longitudinal studies over a full professional season (e.g., Clemente et al., Nobari et al.) [7,15]. Additionally, differences in player positions were not analyzed and it could influence the data analysis. For instance, Clemente et al. [7] found small-to-moderate effect size differences between different playing positions for the number of sprints in acute load, TM, and TS through different external load metrics. Moreover, the present study does not consider individual differences in Acc and Dec capacities that can result in different results [36].

Furthermore, in most studies, the accelerometer is positioned on the upper torso (as in the recent study). Movements of the upper body on the vertical axis that are not part of Acc and Dec will have an impact on the information saved, as reported by Nobari et al. [15]. Finally, the results of the matches were not investigated in this study, nor were the official and friendly matches studied individually. Naturally, the sort of match and its outcome will have an impact on the players' motivation and training both before and after the game. Despite the limitations mentioned, this study was the first one to analyze the variation in TM and TS over the season, and between starters and non-starters through metrics of Acc and Dec.

5. Conclusions

According to the results of a recent study, it seems that TM and TS derived from Acc and Dec are suitable factors for monitoring the training and fitness of football players working in professional teams. The major finding of this study was that when the team leaves the pre-season preparation period and enters the competition season, the exercises performed do not provide the necessary workload for non-starter players. As a result, some physiological adaptations such as speed, agility, cardiorespiratory endurance, aerobic capacity, and anaerobic will not occur in these players due to the low workload of training, and not experiencing high workload in official matches and training. According to the information provided, coaches and researchers are advised to check the weekly TM and TS of starters and non-starters for a better periodization of training and to apply the appropriate workload. In the post-match recovery training session for starter players, non-starter players should experience a higher workload in training that is close to the match conditions.

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