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Two or Four Weeks Acute: Chronic Workload Ratio Is More Useful to Prevent Injuries in Soccer?

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Abstract: This study was conducted to determine if the acute: chronic workload ratio (ACWR) is related to the incidence of non-contact injuries. The purpose is to compare the external load of injured and non-injured soccer players with the same characteristics, such as position and age. The present analysis considers both the four and the two weeks preceding an injury. Physical characteristics were recorded and analyzed through global positioning systems (GPS) evaluation over one season of 24 competitive microcycles, 144 training sessions, and 32 matches in a total of 35 professional soccer players from the Greek Super League 1 and Super League 2. The loads calculated were total distance (TD), 15–20 km/h, 20–25 km/h, 25–30 km/h, accelerations (ACC) > 2.5 m/s^2, and decelerations (DEC) > 2.5 m/s^2). Nine injured athletes exceeded the critical threshold of an ACWR > 1.3 several times compared with non-injured athletes that did not reach this level. The present study showed that ACWR is related to a subsequent occurrence of injury but that the threshold of an ACWR can vary. This seems to be mainly influenced by assessing the load of the last two weeks compared with that of the four weeks before the injury.

Keywords: GPS; external load; ACWR; football; non-contact injuries

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1. Introduction

Soccer is the most popular sport in the world. With demands on players constantly increasing, the risk of non-contact injury is high, and most soccer injuries occur in athletes' lower extremities [1].

These specific injuries, in addition to the harm caused by immediate tissue damage, are an important predisposing factor for new injuries [2] and enhance the appearance of functional asymmetries, with long-term shifts of mechanical loads in collateral joints, muscles, or even the opposite lower extremities to those which received the highest load. Based on Inklaar's [3] theoretical model of soccer injury induction, the causal factors which lead to injuries are divided into endogenous and exogenous. Indicators of external load are the total distance travelled, decelerations, and accelerations [4], as well as distances travelled at high speed, together with sprints [5,6]. These indicators were recorded using global positioning systems (GPS) technology [7,8].

In an attempt to quantify the external burden, researchers have proposed the acute: chronic workload ratio (ACWR) to investigate its relationship with the occurrence of injury [9–12]. The ACWR index records the external burden of the athlete (workload) during one week (acute workload) and compares it to the external burden in the previous four weeks (chronic workload).

Research on this specific subject has increased in recent years [13]. The most recent research has recorded the characteristics of the external burden and quantified them through the ACWR method to predict the probability of a non-contact injury in percentage terms. More specifically, some studies, such as Bowen et al. [14], fully support the results of the relationship between ACWR and non-contact injuries in soccer and rugby which correlate to a significantly lower burden over the last week compared with that over the previous three weeks [15] or the continued high burden of the high risk of injury through ACWR [10–12,16–18]. In contrast, other studies report that the reduced chronic load compared with the immediate (last week) load can cause injury to an athlete [19,20].

On the other hand, further research does not support the relationship of ACWR with non-contact injuries. More specifically, no differences were found in accumulated weekly loads and ACWR calculations regarding injured athletes [21], a conclusion which was supported by related research [22–24], while Impellizzeri et al. [13] mentions that ACWR is a rescaling of the explanatory variable (AL, numerator), in turn magnifying its effect estimates and decreasing its variance despite conferring no predictive advantage.

No soccer research to date has investigated external load in two different periods (the fourth and second week before injury), only the internal load of the session rating of the perceived exertion (s-RPE). Delecroix et al. [20], reporting on acute: chronic workloads using combinations of two, three, and four weeks, provided some evidence to predict an injury, but not to an absolute degree. Fanchini et al. [22] provided evidence for internal load as a risk factor for non-contact injury.

Our study will hence make a distinct contribution to the data comparing the burden in injured and uninjured soccer players, with evidence that will concern the separate management that should exist in the four weeks and the two weeks before the injury. The principal aim is to ensure the health of soccer players, freeing clubs to a large extent from the additional financial exposure and rating losses that follow soccer injuries [25].

2. Materials and Methods

2.1. Participants

Thirty-five Greek professional soccer players (21.1 ± 0.6 years, 180.4 ± 2.6 cm, 76.2 ± 3.8 kg, 6.5 ± 1.1% body fat) participated in this study. Before the start of the study, all testing procedures were fully explained in detail to participants. A consent form for participation in the study was read and then signed by the participants. Moreover, the study was approved by the ethical committee of the Aristotle University of Thessaloniki (96/2021) in accordance with the ethical standards in sport and exercise research.

2.2. Experimental Design

The external load of soccer players was recorded and evaluated using GPS technology (Vector S7, Catapult, Catapult Sports Ltd., Melbourne, Victoria, Australia) at a frequency of 10 Hz, the reliability of which was demonstrated in research by Clavel et al. [26] during the entire 2021–2022 season. In total, the study lasted for 24 competitive microcycles and 144 training units. During the specific weeks studied, there were 16 microcycles, during which there was an official match in the middle of the week. Both the 32 official matches and the training sessions were held on outdoor pitches with natural grass.

2.3. External Load Analysis

Subjects wore a GPS device during all training sessions and official matches, which was placed on their upper back (the GPS device is worn in a specially designed vest). Each player used the same device during the research period. High-speed running of 14.4–19.8 km/h, very high-speed running of 19.8–25.0 km/h, and sprints of >25.0 km/h were evaluated, as well as accelerations with deceleration in zones of <2.5 m/s^2.

Loads were analyzed into weekly plans, where training days were separated. The days with a minus (MD-) refer to the days that are before the next match and the days with a plus (MD+) refer to the days after the previous match. Each weekly block consists of the weekly match day (MD) and all training days are coded as MD-6, MD-5, MD-4, MD-3, MD-2, MD-1. For nine-day microcycles, match—MD + 1 = recovery, MD + 2 = rest, MD-7, MD-6, MD-5, MD-4, MD-3, MD-2, MD-1; for eight-day microcycles, match—MD + 1 = recovery, MD + 2 = rest, MD-6, MD-5, MD-4, MD-3, MD-2, MD-1; for seven-day microcycles, match − MD + 1 = recovery, MD + 2 = rest, MD-5, MD-4, MD-3, MD-2, MD-1; and finally, for six-day microcycles, MD + 1 match = recovery, MD + 2 = rest, MD-4, MD-3, MD-2, MD-1. For the reliability and validity of the study, only data from soccer players performing the full daily training program and participating in matches accordingly were used, and data from goalkeepers and the soccer players whose total load (TL) was manipulated during this period due to fatigue or injury management were removed. All athletes were fully familiarized with the experimental procedures. Soccer players who had completed at least 90% of the total obligations (training, matches) during one week participated in the research process. ACWR used the data collected at four weeks and two weeks to create the first value before the microcycle in which the soccer player was injured. Chronic workload was calculated as the four-week and two-week immediate workload, and ACWR was calculated by dividing the immediate by the chronic workload (load accumulated during the week the athlete was injured/average of the previous four weeks or two weeks). Risk zones were defined as values <0.80 and >1.3 [10].

2.4. Definition of Injury

Only non-contact injuries were included in the study. A doctor always gave the final opinion on an injury after the necessary tests had been conducted. Injuries were classified as minimal (1–3 days lost of active participation), mild (4–7 days lost), moderate (1–4 weeks lost), and severe (4+ weeks lost) [27]. In total, the injuries recorded in the survey were mild and moderate, according to the previous formulation.

Injury incidence was reported in absolute numbers and as an injury incidence rate for the number of injuries per 1000 h of participation in matches and training [27].

2.5. Statistical Analysis

IBM SPSS, version 25 (IBM Corp., Armonk, NY, USA) software was used for statistical analysis. Continuous variables were expressed as mean with standard deviation. Because of the small sample size (N = 18), we used nonparametric controls. For all tests, statistical differences were determined to be significant at $p < 0.05$.

We used the Wilcoxon test to compare the differences between the two comparison groups (injured athletes vs. non-injured athletes). Each observation in one sample is linked to an observation in the other sample as well (same group, same position, and similar age).

3. Results

Nine soccer players were injured without contact during competitive microcycles. Of these, four were injured in the hip adductors, two were injured in the area of their biceps femoris, another two experienced a muscle injury in the gastrocnemius, while one was injured in the quadriceps muscle. The overall rate of non-contact injuries during the competition season (over 24 microcycles) was 4.5/1000 h.

3.1. ACWR at Four Weeks before Injury

In Table 1, the data are presented in total in the analyzed categories and are listed in comparison with the soccer players who were not injured and played in the same position, were of a similar age, and took part in the research process during the same competitive microcycles. It is observed that in no case did soccer players who were not injured exceed the ACWR limit at values <0.80 and >1.3, in contrast to soccer players who were injured. Based on the results in the table below, there is a statistically significant difference of the ACWR index in the categories Distance Speed Range (15–20 km/h), Distance Speed Range (20–25 km/h), and Accelerations (>2.5 m/s^2). The highest ACWR value for injured soccer players is observed in the Distance Speed Range category (>25 km/h) and is 1.58, followed by the Accelerations (>2.5 m/s^2) and Decelerations (>2.5 m/s^2) categories, respectively, whose ACWR values exceeds the limit at 1.32. The results of injured and no injured soccer players for four week model presented in Figure 1.

Table 1. ACWR values for four weeks model (mean ± SD).

	Injury						*p*-Value
	No		Yes		Total		
	Mean	SD	Mean	SD	Mean	SD	
ACWR—Total Distance (km)	1.07	0.07	1.25	0.30	1.16	0.23	0.133
ACWR—Distance Speed Range (15–20 km/h)	0.92	0.04	1.22	0.13	1.07	0.18	>0.001
ACWR—Distance Speed Range (20–25 km/h)	1.00	0.30	1.20	0.27	1.10	0.30	0.047
ACWR—Distance Speed Range (>25 km/h)	1.12	0.32	1.58	0.70	1.35	0.58	0.085
ACWR—# of Accelerations (>2.5 m/s^2)	1.07	0.13	1.32	0.39	1.19	0.31	0.034
ACWR—# of Decelerations (>2.5 m/s^2)	1.07	0.12	1.32	0.36	1.20	0.29	0.063

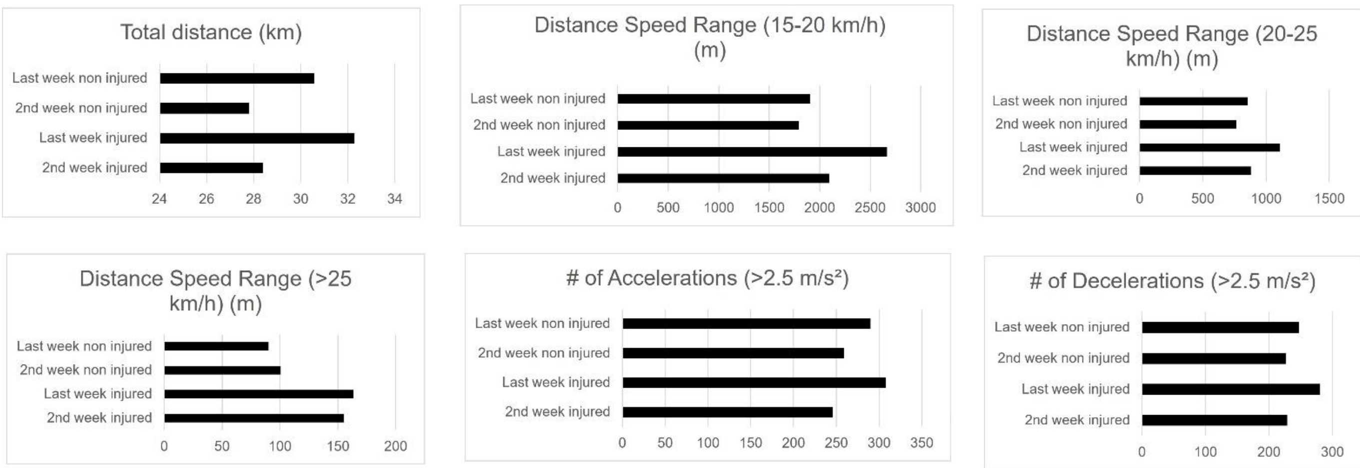

Figure 1. Values of injured and no injured soccer players for four-week model. # denotes number.

3.2. ACWR at Two Weeks before Injury

In Table 2, the total data are presented in the analyzed categories and listed in comparison with the soccer players who were not injured and played in the same position, were of a similar age, and took part in the research process during the same competitive microcycles. It is observed that no uninjured soccer player exceeded the ACWR limit at values <0.80 and >1.3, in contrast to injured soccer players. Based on the results in the table below, a statistically significant difference in the index is obtained in the ACWR in all six categories analyzed and related to Total Distance (km), Distance Speed Range (15–20 km/h), Distance Speed Range (20–25 km/h), Distance Speed Range (>25 km/h), Accelerations (>2.5 m/s^2), and Decelerations (>2.5 m/s^2). The highest ACWR value for injured soccer players is observed in the Distance Speed Range category (>25 km/h) and is 1.47. The results of injured and no injured soccer players for two week model presented in Figure 2.

Table 2. ACWR values for two weeks model (mean ± SD).

	Injury						
	No		Yes		Total		*p*-Value
	Mean	SD	Mean	SD	Mean	SD	
ACWR—Total Distance (km)	1.02	0.08	1.14	0.12	1.08	0.12	0.026
ACWR—Distance Speed Range (15–20 km/h)	0.93	0.04	1.08	0.04	1.00	0.09	>0.001
ACWR—Distance Speed Range (20–25 km/h)	0.95	0.18	1.15	0.24	1.05	0.23	0.042
ACWR—Distance Speed Range (>25 km/h)	1.03	0.24	1.47	0.35	1.25	0.37	0.009
ACWR—# of Accelerations (>2.5 m/s^2)	0.99	0.11	1.16	0.14	1.08	0.15	0.010
ACWR—# of Decelerations (>2.5 m/s^2)	0.99	0.12	1.16	0.12	1.07	0.15	0.010

Figure 2. Values of injured and non-injured soccer players for two-week model. # denotes number.

4. Discussion

This research gives a direction for training methods that a technical staff could follow to prevent non-contact injuries through the individual monitoring of each professional soccer player during the playing season. The following observations were made. First, the results were related to the overall incidence of injuries among athletes as there was a higher index through ACWR for soccer players who were injured. Second, the ratios that most often resulted in a non-contact injury were at levels that often approached or exceeded 1.3. Thirdly, of the six parameters (TD, 15–20 km/h, 20–25 km/h, >25 km/h, ACC > 2.5 m/s^2, DEC > 2.5 m/s^2), in at least three of these, recorded and analyzed in four-week (ACWR4) and two-week (ACWR2) blocks, injured soccer players received a higher load than in the previous. Fourth, significant changes were observed mainly in the speed parameter at 25–30 km/h, which negatively affected the injured footballers.

In the comparison of specific weeks (second and fourth) before the injury and, more specifically, in the four-week period, the following observations were made. Soccer players who were not injured for all parameters cumulatively were at 1.04, and those who were injured were at 1.18, while at two weeks the soccer players who were not injured were at 0.98, and those who were injured were at 1.08. In the *p*-value category, significance is observed at four weeks before the injury for three of the six categories, while at two weeks, all six categories were statistically significant and negatively affected an injury. In the analysis of both weeks, there is a large discrepancy in the Distance Speed Range category (>25 km/h), with 1.58 for the four weeks and 1.47 for the two weeks for the non-contact-injured soccer players.

Using ACWR for injury risk and comparing external loads, it was found that the ratio of immediate to chronic loads (absolute total distance) predicted injuries in elite rugby players [12]. Bowen et al. [11], investigating data from young elite-level soccer players, showed that three-week accelerations in particular were the strongest predictor of injury. Decelerations were particularly associated with a greater risk of non-contact injury by the same authors in 2019, and, in collaboration with professional soccer players, ACWR was directly associated with injury risk (except distance at high speed). These results contrast with Malone et al. [28], who concluded that athletes should perform maximal velocities at high rates during training to protect against subsequent soft tissue injury. Moreover, according to Buchheit [29], and since soccer players have international obligations with their national teams, contradictory data exist due to the different recording systems used by the teams for which they play, which necessarily makes predicting non-contact injuries much more difficult.

Our study found a correlation between ACWR scores and injury frequency over an entire season in professional soccer players. In the current study, nine injured soccer players repeatedly received a more significant load than the previous four (ACWR4), especially at two weeks (ACWR2). Essentially, it is observed that the considerably increased load in one microcycle, always compared with the previous four and two weeks, does not keep a soccer player in a good playing condition which will protect them against injury during the game to be played at the end of that particular microcycle.

In addition, the current research results show that when the volume of running speed with higher intensities (15–20 km/h, 20–25 km/h, <25 km/h) increased, non-contact injuries occurred. A possible relationship between accelerations and decelerations in the occurrence of non-contact injury was also observed, as confirmed by Schache et al. [30], who report that these concentric and eccentric movements are responsible for most specific injuries. Essentially, we have to focus on high-speed running (15–20 km/h, 20–25 km/h, <25 km/h) which, according to our research, has a greater negative impact on a football player when they exceed the previous load. This was found mainly in the analysis of two, and less so in four, weeks. Limitations of this study could include that the football players who participated in the research may not have had exactly the same participation time in the team's official match.

5. Conclusions

In the present study, both models comparing ACWR4 and ACWR2 give indications of the possible occurrence of non-contact injury in professional soccer players. It was observed that the ACWR2 model may be a more sensitive indicator as the differences were more pronounced in more of the examined variables. From the above, it can be seen that staff dealing with the physical condition and prevention of injuries in professional soccer players should consider the indications from the ACWR4 and ACWR2 indicators. We suggest the ACWR2 model as the most applicable as it is more immediate (two weeks versus four weeks) and thus a soccer scientist will be able to control the loads better since he will need fewer days to analyze the data (of training and matches). Moreover, because the burden on soccer players not only consists of running but can also include strength training, it is recommended that future research include these elements of burden in attempts to predict injury.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available upon request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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