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Original Research

Relationship Between Variations Accumulated Workload and Sprint Performance in Elite Adolescent Soccer Players

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Abstract

Background: The aim of this study is to analyze the relationship between the accumulated training load parameters (i.e., acute (AWL), chronic (CWL), acute: chronic workload ratio (ACWR), training monotony (TM), and training strain (TS)) and sprint performance variations in elite adolescent soccer players, taking into account the maturation status of the players. Besides, we aimed to use regression models with mentioned parameters, sprint level, and peak height velocity (PHV) as predictors to explain variations in sprint performance during the in-season. **Methods**: Twenty-seven U16 soccer players (age: 15.5 ± 0.2 years, height: 171 ± 7.3 cm, body mass: 59 ± 6.1 cm, PHV: 14.4 ± 0.7) from one elite soccer national league club were evaluated. In this study was a cohort with monitoring the daily workload for 15 weeks in the competition season: early-season (EaS) weeks (w) W1 to W5; mid-season (MiS) W6 to W10; and end-season (EnS) W11 to W15. Anthropometric and PHV were assessed at the beginning of the season and sprint test was assessed before and after the season. **Results**: Results showed that there were some significant variations in workload parameters (sprint, AWL and TM) over a soccer season. Regarding comparisons between EaS vs. EnS, there were significant differences in Sprint ($p \leq 0.01$; ES: –0.28) and CWL ($p \leq 0.01$; ES: –0.80). Sprint performance can be estimated by ACWR, TM, TS and PHV values ($R^2 = 0.65$). **Conclusions**: The present study revealed that sprint performance improved throughout the season in young soccer players, with significant intra-season variations, especially in CWL and ACWR load variables (Eas and Mid). In addition, it was observed that maturation did not have a significant effect on the change in sprint performance. This study clearly showed that there is a relationship between sprint performance and accumulated workload variables and that the significant change in sprint performance can be explained by load variables such as AWCR, TM, and TS.

Keywords: linear sprint; running speed; training strain; football; in-season; maturation; ACWLR; training monotony

1. Introduction

Soccer is an intermittent sport characterized by interspersed multiple high-intensity short activities (e.g., running and sprinting) with predominantly low-intensity activity (e.g., standing and walking) demands [1,2]. Even from a young age, modern soccer requires high levels of physical fitness development [3,4]. According to time–motion analysis, elite professional adult soccer players cover a total distance of approximately 10–12 km at an average intensity close to the anaerobic threshold (80–90% of maximum heart rate) [5,6], and they perform 1350 activities every 4–6 seconds during the game. Approximately 150 to 250 of these activities are short, intense, and explosive activities associated with maximal sprint, acceleration, and change of direction [7,8]. On the other hand, the activity profiles of young soccer players (distance covered, high-intensity activity and sprinting) during the match are low. It was shown in a study that elite young soccer players between the ages of 13–18 covered a distance of approximately 6.5–9.0 km during the match, and high-intensity activity was carried out with 670–970 m of this distance, and 190–670 m was the sprint distance [9]. Considering the above values, although energy is supplied by the aerobic system for most of the soccer game, during the performance of continuous explosive activities the anaerobic system works actively, such us keeping control of the ball against defensive pressure, jumping, tackling, kicking, turning, sprinting, changing of direction during the game [6,10,11]. Therefore, soccer players need to have well-developed aerobic and anaerobic metabolisms in order to meet and sustain the necessary physical and physiological demands, in turn providing the best performance during the match [7,12,13].

Considering that the most decisive movements in soccer take place in areas smaller than 10 m^2 [14], high power locomotor activities such as sprinting can be the main factor factor in the sucess of high-level soccer performance [9–11,13]. Sprinting represents a multidimensional movement skill that involves an explosive concentric, and stretch-shortening cycle (SSC) force production, using a number of lower-limb muscles [15,16]. However, it can be particularly exploited by the players' ability to use and optimize the elastic and neural properties of the SSC after plyometric training [17]. Sprint performance is widely used as a talent identification indicator to distinguish between elite and non-elite young soccer players [1], and to achieve advantages in attacking and defensive situations [18]. Time-motion analysis show that short sprints frequently take place approximately every 90 seconds, each lasting an average of 2–4 seconds during the professional soccer matches [6,19]. In a one study, straight sprinting was observed to be the most frequent action before scoring goals for both striker and assist player in youth soccer player [20]. Biological maturity is identified as the time required to reach the adult stage and is characterized by the process of change in sexual, morphological, neural and hormonal, somatic, and skeletal factors [14,21]. Predicted maturity offset, defined as the age at which the greatest increase in height occurs (age at peak height velocity; PHV), is commonly used as an indicator of somatic maturity timing and status [21,22]. In growth spurt, around PHV, there is a large within-group variation in body height, ranging from 8.2 to 10.3 cm per year [23]. In literature, regarding the age at which PHV usually occurs in studies on male youth soccer players, one study reported that the mean age of PHV was 14.4 ± 0.65 years (range, 12.8–16.5 years) [24], and another study showed that the mean age of PHV was 13.60 ± 0.85 years. Also, in the same study, it was stated that a PHV was delayed by $>$14.45 years, whereas a PHV $<$12.75 years was advanced [25]. However, the hormonal and physiological level that drive the maturation thresholds are at critical impact on physical performance by regulating their adaptation to training responses [26]. With regards to this, Meylan *et al.* [27] and Philippaerts *et al.* [28] showed that the highest physical performance characteristics such as speed, strength and power coincided with the onset of PHV in young male athletes. Clearly demonstrating the synergistic adaptation, which refers to the relationship between specific adaptations of training load and adaptations related to growth and maturity. Thus, it could be argued that the high neural demand of plyometric training provides a stimulus that coincides with the natural adaptive response of pre-PHV boys, which results from growth and maturation in youths [13,29,30]. Moreover, sprinting performance are likely to develop throughout childhood as children grow and mature [15], especially in youth soccer players [21]. For instance, it was demonstrated that sprinting performance improved significantly more at the time of PHV from pre-to-mid-PHV (39.8%) (at the time of PHV) than from mid-to-post-PHV participants (9.49%) [31]. There are several possible explanations for the maturation-dependent evolution of sprint performance. Also, the Rumpf *et al.* [31] noted that maturation affected the vertical stiffness and the ability to absorb and generate power, which were important determinants in the development of maximum sprint performance. Additionally, Fernández-Galván *et al.* [14] suggested that sprinting performance enchanced more rapidly in the post-PHV phase because of the increased strength and power generation that maturity naturally provides (i.e., increased stride length and frequency, and decreased ground contact time).

During the season, it is recommended that the applied workloads should be sufficient to improve the physical performance quality of the players [18]. Monitoring the training load is seen as an important factor to determine whether the athletes are adapting to the training program, to optimize the training process, and to minimize the risk of non-functional overreaching, disease and/or injury [32,33]. Sports and exercise scientists recognize that "training load" includes of both "external" and "internal" domain [32,34]. External training load is defined as the activity profiles of players or physical work during the training sessions (for example, total distance covered, acceleration, deceleration or metabolic power), while internal training load includes all psychophysiological responses that occur during execution of the exercise predicted in response to external training load (for example, degree of perceived exertion (RPE), heart rate (HR)) [33,35]. session-RPE (s-RPE) is an easy-to-use [36,37], and the most common valid/reliable method for measuring internal training load and accumulation between sessions in team sports [38]. It was previously demonstrated that sRPE was associated with the HR-derived measures of training intensity in professional soccer players [39]. Besides s-RPE, recent studies have shown that parameters derived from the internal and external training load of soccer players are also frequently used in the monitoring training load throughout the season. These parameters are the acute (AWL), chronic (CWL), acute: chronic workload ratio (ACWR), training monotony (TM), and training strain (TS). Haddad *et al.* [38] stated that these parameters mentioned above can be calculated from the session-RPE method data of a training microcycle. Higher TM scores indicate lower standard deviations of the mean, i.e., small variations within a week, while higher training strain points out larger acute loads applied with small variations during the week [40]. These high scores may be associated with disease incidence, poor performance, and the onset of overtraining [36,38]. With this, the use of the ACWR to understand changes in the load and how these changes relate to risk of injur, has received increasing scientific attention [41,42]. ACWR is calculated by dividing the AWL (the workload of the week preceding the injury, fatigue component) by the CWL (the average workload of the four weeks preceding the injury, fitness component) [41,42]. Considering the training intensity parameters mentioned above, coaches can determine the physical and physiological effects of training sessions on players.

Furthermore, Nobari *et al.* [43] emphasized that accumulated training load and maturation status play a critical role in the physical capacity changes observed across the season, especially sprinting which was demonstrated to improve naturally with age, reported that improvements in performance result from changes in neuromuscular mechanisms related to growth and maturity [44]. Therefore, coaches need to take these two factors into consideration in order to carefully interpret the fitness variations in their players and to adjust the types of training they will perform according to the maturation level of the players. As far as we know, there is no study examining the relationship between the accumulated training load (AWL, CWL, TM, TS, and ACWR) and the changes in sprint performance, that also takes into account the maturation factor in elite young soccer players. Considering the advantage of having a good sprint performance in the soccer game, it is extremely important to optimize the training load-rest relationship throughout the season, and to improve the parameters related to speed. The aim of this study is to analyze the relationship between the accumulated training load parameters and sprint performance variations in elite adolescent soccer players, taking into account the maturation status of the players. According to the relevant literature examining the relationship between training load variables and different physical fitness characteristics (except sprinting) [4,13,43]. As a result, based on the literature presented [4,45–48], we hypothesized that the accumulated training load and maturation maybe partially explain variation of sprint performance during the competitaion season in elite youth soccer players.

2. Materials and Methods

2.1 Participants

Twenty-seven U16 soccer players (age: 15.5 ± 0.2 years, height: 171 ± 7.3 cm, body mass: 59 ± 6.1 kg, PHV: 14.4 ± 0.7) from one elite soccer national league club were evaluated. This team completed 57 training sessions and 15 competitive matches. The inclusion criteria included were (i) players who attended at least 90% of training sessions during the course of the season; (ii) players who remained injury-free during the study; (iii) players that did not take part in any other training programme; (iv) during the trial, the participants did not take any dietary supplements. There was also a compensation training session for players who did not participate a match during a week. The dominant training and match microcycle is shown in Fig. 1 during the competition season. Players received a clear explanation of the study and written consent was obtained. Experimental procedures were approved by the Ethics Committee of the University of Mohaghegh Ardabiliand and the recommendations of Human Ethics in Research were followed according to the Helsinki Declaration. Written informed consent was obtained from both the players and their parents before beginning the investigation.

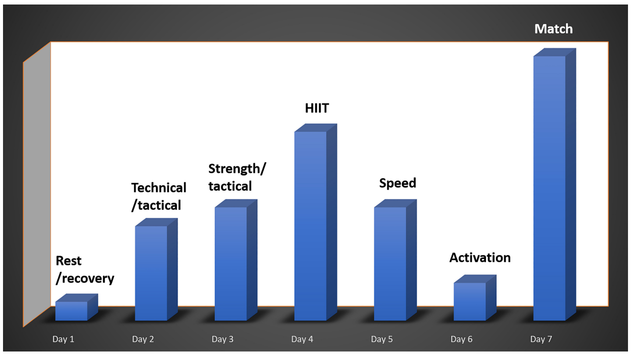

Fig. 1. The dominant training microcycle during the competition season.

2.2 Design

In this study there was a cohort with monitoring the daily workload for 15 weeks in the competitive season: early-season (EaS) weeks (w) W1 to W5; mid-season (MiS) W6 to W10; and end-season (EnS) W11 to W15 (Fig. 2). Participants were assessed on anthropometric measurements, maturity and sprint performance by the same group of researchers during the complete study, at the same time of the day (8–11 Am) [49]. The first evaluations were performed at 16 °C and 27% humidity and the second stage evaluations were performed at 12 °C and 35% humidity. All tests and exercises were performed on natural grass.

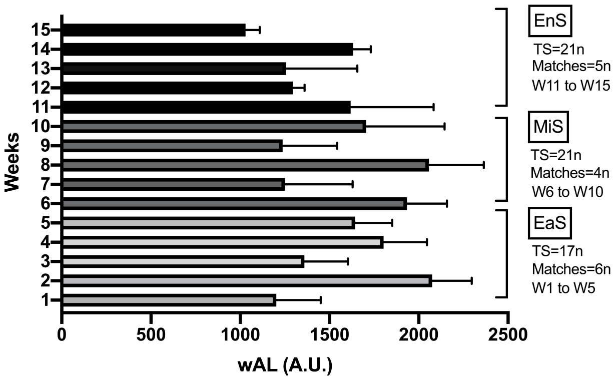

Fig. 2. Research outline of the weekly monitoring on training and match load and assessed sessions during the competition season. EaS, early-season; Mid, mid-season; EnS, end-season; wCL, weekly accumulated chronic workload; TS, training sessions; A.U., arbitrary unit.

Height was measured with a portable stadiometer (Seca model 213, Hamburg, Germany). Body mass was performed using portable weighing scales (Seca model 813, United Kingdom). This data was used to distinguish the maturity offset and age at PHV of the subjects, the down formula was used [50], as follows: Maturity offset = –9.236 + 0.0002708 (leg length × sitting height) – 0.001663 (age × leg length) + 0.007216 (age × sitting height) + 0.02292 (weight by height ratio), where R = 0.94, R^2 = 0.891, and SEE = 0.592) and for leg length = standing height (cm) – sitting height (cm) was used. We used only PHV based on the aim of the study.

2.3 Quantification of Session-Rated of Perceived Exertion

The intensity of training sessions was estimated using the Borg CR-10 rate of perceived exertion (RPE) scale [50]. Thirty minutes after the end of the training session each player reported his RPE for each session confidentially without knowledge of other players' ratings. As a measure of internal load, the session-RPE was derived by multiplying RPE and session duration (min) [36]. Players were previously familiarized with the scale during two years at the club.

2.4 Workload Parameters

Additional, workload (WL) parameters were calculated. A total load of daily training during the week was considered as weekly AWL; the uncoupled formula [51] was used to obtain the weekly chronic (CWL) and acute-chronic workload ratio (ACWR); weekly training monotory (TM) (weekly AWL ÷ standard deviation (SD) of this week's AWL); and eventually weekly training statin (TS) (weekly AWL × weekly TM). These 15 weeks of the full competitive season were divided into three periods early-season (EaS) = W1 to W5, mid-season (MiD) = W6 to W10 and end-season (EnS) = W11 to W15.

2.5 Sprint Performance

Each participant performed two maximal 30-m sprints, measured with one pair of the electronic timing system sensors (Newtest Oy, Finland) mounted on tripods that were set at hip height and was positioned 3 m apart facing each other on either side of the starting line. The participants commenced the sprint from a standing start, 0.5 cm behind the first timing gate. Between two trials recovery was 3 minutes. The best time was recorded for analysis. Tests were performed outdoor and on natural grass.

2.6 Statistical Analysis

Data were analyzed in SPSS Version 25 (IBM SPSS Inc., Chicago, IL, USA) except for multiple linear regression and Akaike information criterion (AIC), which were calculated using Graph-Pad Prism 9 (GraphPad Software Ind, San Diego, California, CA, USA). Results are expressed as mean ± standard deviations (SD). The significance level was set at $p < 0.05$. All variables used in the study were checked by Shapiro–Wilk test for normality of distribution before the analyzed. Pearson and Spearman correlation coefficient was applied to examine the relationship between the WL parameters, maturity and PHV. Paired-tests with a 95% confidence interval (CI) were used to compare the three periods of the season (EaS, MiD and EnS) once variables obtained normal distribution. Non-parametric analyses were used to calculate differences within (Wilcoxon test) the three periods of the season. Cohen's d effect sizes were calculated and expressed with a 95% CI to document the size of the statistical effects observed and defined as <0.2 = trivial, 0.2 to 0.6 = small effect, >0.6 to 1.2 = moderate effect, >1.2 to 2.0 = large effect and >2.0 = very large [52]. Finally, a multiple linear regression analysis was applied to examine the relationship between the percentage of reports sprint test, with variations in workload parameters and maturity variables. The AIC for each model's regression was additionally calculated, to support inferences about the model's suitability.

3. Results

In Table 1 significant positive correlations were shown between Sprint EaS with Sprint EnS (r = 0.965; $p \leq 0.01$), AWL MiD (r = 0.548; $p \leq 0.05$), CWL MiD (r = –0.584; $p \leq 0.01$), ACWR EnS (r = 0.458; $p \leq 0.05$), TM EaS (r = 0.579; $p \leq 0.05$) and TS EaS (r = 0.513; $p \leq 0.05$). Likewise, Sprint EnS was associated with CWL MiD (r = 0.543; $p \leq 0.05$) and TM EaS (r = 0.463; $p \leq 0.05$). In addition, AWL EaS was related to AWL MiD (r = –0.429; $p \leq 0.01$), CWL EaS (r = 0.285; $p \leq 0.05$), CWL MiD (r = 0.242; $p \leq 0.05$), TM Eas and MiD (r = 0.601, –0.500; $p \leq 0.01$), and TS EaS and MiD (r = 0.685, –0.518; $p \leq 0.01$). There were associations between AWL MiD and CWL EaS (r = –0.299; $p \leq 0.05$), ACWR MiD and EnS (r = 0.465, –0.244; $p \leq 0.05$), TM EaS, MiD and EnS (r = –0.374, 0.447, –0.365; $p \leq 0.05$) and TS EaS, MiD and EnS (r = –0.419, 0.472, –0.231; $p \leq 0.05$). Further, AWL EnS was related to ACWR MiD (r = –0.279; $p \leq 0.01$). Additionally, CWL EaS was associated with CWL EnS (r = –0.263; $p \leq 0.05$), TM MiD (r = –0.285; $p \leq 0.05$). Moreover, ACWR EaS was related to ACWR MiD (r = 0.718; $p \leq 0.05$). There were associations between TM EaS and TM MiD (r = –0.438; $p \leq 0.05$) and TS EaS and MiD (r = 0.943, –0.451; $p \leq 0.01$). Furthermore, TM MiD was associated with TS EaS and MiD (r = –0.453, 0.966; $p \leq 0.01$). Finally, TS EaS was related to TS MiD (r = –0.476; $p \leq 0.01$).

Descriptive workload and sprint results and comparison between EaS, MiD and EnS are presented in Table 2. Regarding data, there was no difference between EaS vs. MiD ($p > 0.05$; ES: –0.34 to 0.06) in all variables, except to ACWR ($p \leq 0.05$; ES: –3.02). The major findings between MiD vs. EnS were found in CWL ($p \leq 0.01$; ES: –1.51) and ACWR ($p \leq 0.05$; ES: –3.02). Regarding comparisons between EaS vs. EnS, there were significant differences in Sprint ($p \leq 0.01$; ES: –0.28) and CWL ($p \leq 0.01$; ES: –0.80).

Table 1. Pearson and Spearman correlation analysis between the workload parameters and sprint test.

Variable	$\beta0$	$\beta1$	$\beta2$	$\beta3$	$\beta4$	$\beta5$	$\beta6$	$\beta7$	$\beta8$	$\beta9$	$\beta10$	$\beta11$	$\beta12$	$\beta13$	$\beta14$	$\beta15$	$\beta16$	$\beta17$
PHV ($\beta0$)	1																	
SPRINT1 ($\beta1$)	–0.206	1																
SPRINT2 ($\beta2$)	–0.169	0.965**	1															
AWL1 ($\beta3$)	–0.070	0.413	0.327	1														
AWL2 ($\beta4$)	0.014	0.548*	–0.387	–0.429**	1													
AWL3 ($\beta5$)	–0.110	–0.236	–0.226	0.001	0.061	1												
CWL1 ($\beta6$)	–0.071	–0.107	–0.108	0.285*	–0.299*	–0.168	1											
CWL2 ($\beta7$)	0.070	–0.584**	–0.543*	0.242*	–0.134	0.093	0.091	1										
CWL3 ($\beta8$)	0.224	0.093	0.031	–0.201	0.176	0.188	–0.263*	–0.002	1									
ACWR1 ($\beta9$)	0.138	0.254	0.216	0.124	0.095	–0.018	0.182	0.198	0.187	1								
ACWR2 ($\beta10$)	0.268	0.151	0.130	–0.023	0.465**	–0.279**	–0.086	0.099	0.045	0.718**	1							
ACWR3 ($\beta11$)	0.405	0.458*	0.355	0.001	–0.244*	0.011	0.046	0.043	0.138	0.006	–0.194	1						
TM1 ($\beta12$)	0.156	0.579*	0.463*	0.601**	–0.374*	0.108	0.197	0.070	–0.071	0.015	–0.247	–0.044	1					
TM2 ($\beta13$)	0.351	–0.294	–0.218	–0.500**	0.447**	–0.015	–0.285*	–0.151	0.056	0.094	0.153	–0.103	–0.438**	1				
TM3 ($\beta14$)	0.053	0.216	0.190	0.208	–0.365**	0.058	0.239	–0.111	–0.108	0.015	–0.088	–0.009	–0.063	0.014	1			
TS1 ($\beta15$)	–0.184	0.513*	0.419	0.685**	–0.419**	–0.034	0.294	0.083	–0.217	0.025	–0.233	–0.081	0.943**	–0.453**	–0.018	1		
TS2 ($\beta16$)	0.438	–0.350	–0.283	–0.518**	0.472**	0.025	–0.351	–0.118	0.126	0.102	0.187	–0.107	–0.451**	0.966**	0.023	–0.476**	1	
TS3 ($\beta17$)	0.095	–0.092	0.074	0.052	–0.231*	0.064	0.191	–0.337	–0.023	0.024	–0.186	0.039	–0.087	–0.075	0.516	–0.086	–0.081	1

AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWR = the accumulated acute: chronic workload ration in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season; PHV, Peak height velocity 1: early-season; 2: mid-season; 3: end-season; * Represent demonstrated significance in correlation between two parameters at $p \leq 0.05$ levels; ** Represent demonstrated significance in correlation between two parameters at $p \leq 0.001$ levels.

Table 2. Comparison of different time point in the workload parameters and sprint test.

Variables	EaS *(Mean ± SD)*	MiD	EnS *(Mean ± SD)*	EaS vs. MiD			MiD vs. EnS			Eas vs. Ens		
		(Mean ± SD)		*p*	CI (95%)	Effect size	*p*	CI (95%)	Effect size	*p*	CI (95%)	Effect size
Sprint (s)	4.22 ± 0.26	—	4.14 ± 0.26	—	—	—	—	—	—	<0.001*	0.04, 0.10	–0.28 (–0.39; –0.18)
AWL (A.U.)	1615.5 ± 388.4	1606.3 ± 463.8	1407.6 ± 396.5	0.99	–209.4, 197.6	0.06 (–0.27; 0.40)	0.124	–26.1, 317.4	–0.34 (–0.63; –0.05)	0.113	–22, 301.4	–0.36 (–0.61; –0.10)
CWL (A.U.)	1660.4 ± 183.6	1591.1 ± 233.6	1398.3 ± 217.7	0.377	–31.2, 138.2	–0.34 (–1.91; –1.11)	<0.001*	100.7, 288.9	–1.51 (–1.91; –1.11)	<0.001*	154.5, 342.2	–0.80 (–1.05; –0.56)
ACWR (A.U.)	1.05 ± 0.37	0.94 ± 0.38	0.94 ± 0.36	<0.001*	0.202, 0.413	–3.02 (–3.63; –2.40)	0.022*	–0.357, –0.022	–2.29 (–3.03; –1.56)	0.373	–0.307, 0.070	–0.18 (–0.46; 0.11)
TM (A.U.)	1.25 ± 0.29	1.22 ± 0.40	1.57 ± 1.39	0.99	–0.127, 0.207	–0.01 (–0.47; 0.27)	0.99	–0.294, 0.190	–0.30 (–0.70; 0.10)	0.99	–0.230, 0.205	0.13 (–0.23; 0.49)
TS (A.U)	2074.4 ± 981.5	2134.9 ± 1099.4	1912.1 ± 983.4	0.99	–519.4, 480.5	0.01 (–0.35; 0.36)	0.255	–123.6, 737.7	–0.42 (–0.71; —0.13)	0.195	–88.3, 663.5	–0.31 (–0.59; –0.03)

AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWR = the accumulated acute: chronic workload ration in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season; CI, Confidence interval; EaS, early-season; Mid, mid-season; EnS, end-season; * Represent demonstrated significance in comparison between two time periods at $p \leq 0.05$ levels.

Table 3. Multiple linear regression analysis: percentage of change in sprint with workload and maturity.

Variables	Beta	Estimate	|t|	*p* value	95% CI for estimated	Total predict
Sprint (%)	$\beta 0$	–13.37	5.41	<0.001**	–18.6, –8.07	R^2: 0.65
ACWR (A.U.)	$\beta 1$	0.9621	4.09	0.001**	0.45, 1.46	Estimated R^2: 0.55
TM (A.U.)	$\beta 2$	0.5423	2.22	0.04*	0.01, 1.06	*p*: 0.003
TS (A.U.)	$\beta 3$	–0.0001	2.24	0.04*	–0.001, 0.0004	AIC value: 15.9
PHV (years)	$\beta 4$	0.2818	0.72	0.48	–1.11, 0.55	

AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWR = the accumulated acute: chronic workload ration in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season; PHV, peak height velocity; COD,change of direction; % = the percentage of change in between assessments from early-season to after-season; AIC, Akaike information criterion, and CI, confidence interval; * Represent demonstrated significance at $p \leq 0.05$ levels; ** Represent demonstrated significance at $p \leq 0.001$ levels.

Multiple linear regression analyses were performed to predict the percentage of change in sprint performance based on workload and maturity (Table 3 and Fig. 3). The analysis of sprint showed that there were significant (F (4, 14) = 6.70, $p = 0.01$), with a R^2 of 0.65. Participants showed good predictions for sprint (Y) is equal to Beta0 + Beta1 (ACWR) + Beta2 (TM) + Beta3 (TS) + Beta4 (PHV), where workload parameters were measured as A.U. and PHV was measured as years in order based on the equation.

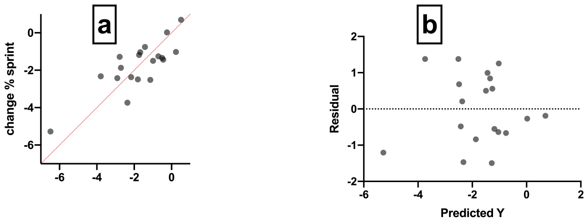

Fig. 3. Prediction of the percentage of change in (a) sprint and residual plots in (b) sprint of multiple linear regression analysis. Note: PHV, Peak height velocity.

4. Discussion

The aim of this study was to analyze the relationships between training WL parameters with variations in sprint performance in under-16 soccer players. The present study revealed that sprint performance improved in EnD compared to EaS independent of maturation, agreeing with our original hypothesis. Furthermore, there were significant variations in workload parameters (CWL and AWCR) over a soccer season. Additionally, significant correlations were found between the sprint performance, and the accumulated workload parameters, which is also in line with our hypothesis. Lastly, sprint performance can be estimated by ACWR, TM and TS values during the 15-week competitive season in young soccer players.

Analyzing the probability of associations between accumulated training load and changes in sprint performance helps determine whether training load is a determinant of these changes or if there are other factors that coaches should be aware of [53]. Having good physical capacity during the season also increases tolerance to training load. In one study, Malone *et al.* [18] expressed that well-developed lower body strength, repeated sprint ability, and speed performance provide better tolerance to higher workloads in team athletes, and are associated with a lower risk of injury. Moreover, previous study indicated that athletes who were slower at 5-m, 10-m and 20-m running distances were at higher risk of injury compared to faster athletes [54]. The present study revealed that the 30 m sprint performance improved during the competitive soccer season (EaS–EnS period). Suporting our results, recent studies demonstrated that sprint performance gradually improved over the course of the season in elite youth soccer players [4,55]. On the contrary, previous studies found that sprint performance (10 m, 30 m) did not change significantly during a season in elite female soccer players, which is not compatible with the results of our study [53,56]. Furthermore, multiple linear regression analysis revealed that maturity had no significant effect on the change in velocity performance during the season in the current study. Our hypothesis that maturation has a significant effect on the improvement in sprint performance was rejected (estimate = 0.28, t = 0.72, $p = 0.48$). Consistent with our results, recent studies showed that maturation did not significantly affect sprint performance [57,58]. In contrast, some studies reported that maturation was effective in improving sprint performance in young soccer players [30,59]. Similarly, Nobari *et al.* [4] found a strong correlation between the development of speed variables and PHV during the season in young soccer players and as a result, they empahized that maturation had a significant effect on the improvement in sprint performance. The reason why the improvement in sprint performance is independent of maturation can be explained as follows; the development of certain speed and power traits during growth and maturation may depend on the stage of development of physiological determinants or mechanisms that support these particular traits [21], such as myelination of motor nerves and neural maturation [43]. Moreover, Myers *et al.* [59] pointed out that measures of relative stifness and relative maximal strength had significant influence on the development of maximum sprint speed in males, independent of maturity in youths.

In literature, there are some studies that test the relationship between WL and variations in physical and physiological variables during the competition season in young soccer players. For instance, it was previously noted that sRPE during the pre-season period were positively and largely associated with (r = 0.70–0.75) variations on 30–15 intermittent fitness test performance in professional soccer players [60]. Another study conducted by Nobari *et al.* [13] stated that a large and moderate relationship was found between accumulated daily loads during one week and peak power and change of direction at different periods of the season. Moreover, the same authors proposed that the CWL and accumulated TM values could be utilised to better clarify the physical capacities of young soccer players. Additionally, another study showed that there were large correlations between cardiorespiratory performance (maximal aerobic speed) and accumulated RPE, and accumulated sRPE [61]. As far as we know, there is no study to examine the relationships between changes the accumulated workload parameters (AWL, CWL, ACWR, TM and TS) and sprint performance over a soccer season in youth soccer players. Therefore, the present data showed that the percentage of change in sprint performance can be predicted by accumulated workload parameters such as the ACWR, TM and TS. With the exception of PHV, these three variables were observed to be significant predictors of the percentage change in sprint performance during the 15-week competitive season. Contrary to our findings, a previous study reported that there was no significant relationship between the ACWR value and the improvement in sprint performance [61], and another study noted that there was no significant relationship between sRPE and fitness status (including 10 m and 30 m sprint performance) in elite female soccer players [20]. Also in these studies, ACWR value is widely used to predict injury risk [19,33], and a recent study suggested that it can be used as a performance monitoring tool for team sports athletes as well as injury prediction [62]. In our study, it was observed that ACWR value was significantly higher in EaS compared to MiD, and significantly higher in MiD compared to EnS (0.94–1.05 A.U). In other words, we can say that the ACWR value is high in EaS and MiD, and gradually decreases towards EnS. There are some findings in these studies that support our results. For instance, Clemente *et al.* [63] is in support of our results, stating that elite volleyball players had a high training load during the early season period. In another study Nobari *et al.* [6] demonstrated that ACWR of elite youth soccer players ranged from 0.90–1.14 A.U. throughout the competitive season. Additionally, Hulin *et al.* [62] stated that high WL ratios ($>$1.5) are related to higher risk of injury. The scores of ACWR over a soccer season corresponds to the "sweet spot" from 0.8 to 1.3 identified by Gabbett [35], which decreases training load-related injury risk. As in our study, Lazarus *et al.* [64] reported that maintaining the ACWR values in the sweet spot range throughout the season was effective in maximizing performance or increasing performance, similar to the risk of injury. The present study also showed that while no significant variations were observed in AWL during the season, significant variations were observed in CWL (EaS $>$ EnD, MiD $>$ EnD). Therefore, we can say that the optimization (load distribution) in ACWR during the season is due to CWL, which may be related to the improvement in sprint performance. In addition, the improvement in sprint performance during a season may be due to differences in training loads (CWL and ACWR) throughout the season, optimal management of training loads (respecting the training principles and biologic individuality), and a good micro and meso cycle planning [53]. Besides the optimization of variations in load parameters (TM, TS, and ACWR), the improvement in sprint performance in our study can be explained by improvements in technical adaptations such as an augmented stride length, a decreased contact time during acceleration, an increase in lower extremity strength and ground reaction forces, and an improvement in body coordination [65].

Furthermore, TM is a measure of daily training variability [39], and variations in training play a critical role in the prevention of monotony formation and the realization of supercompensation. TS, like TM, is also related to level of training compliance, and can increase the incidence of infectious diseases and injuries during periods of high load associated with high monotony [55]. The present study revealed that the significant improvement in sprint performance throughout the season was predicted by the TM and TS variables. In favour of our study, Stochi de Oliveira and Borin [55] reported low monotony values (1.4–1.7 A.U.) during the 20-week season in futsal players leading to an increase in the height of the CMJ and thus a lower extremity strength preformance. The same researchers suggested that distribution ratios of neuromuscular training and tactical technical training throughout the season, as well as TM, provide positive adaptations in lower extremity power performance. Furthermore, another study stated that proper WL distribution or variations prevented maladjustment from sports training and optimized athletic performance (maintaining positive adaptations throughout the training cycle) [65]. Additionally, the present study observed that there were no significant variations in TM and TS values during the 15-week competitive season. Our results were supported in the previous study on professional soccer players conducted by Lu *et al.* [66] stated no significant changes in sRPE-based TM or TS over four weeks. In our study, it is seen that the TM values in the EaS, MiD and EnD periods are around 1.25, 1.22 and 1.57, respectively. Nobari *et al.* [67] reported that TM values in young soccer players varied between 1.19–1.06 A.U. during 20 weeks, whereas TS values varied between 1196.36 and 1735.53 A.U. According to Nobari *et al.* [67], we can say that TM and TS values are lower than our study throughout the season. In an another study, Nobari *et al.* [8] indicated that TM values average 1.2 A.U. during the season in under-16 soccer players. Another study conducted by Miloski *et al.* [68] found the highest TM and TS values during the season to be 1.61 ± 0.3 and 4771.4 ± 1570, respectively. Moreover, Stochi de Oliveira and Borin [55] indicated that that the TS values during the futsal season were between 4000–6000 A.U. and did not exceed 6000 A.U. These values were also reported to be acceptable. According to Foster *et al.* [36], TM values greater than 2 AU, and TS values greater than 6000 A.U., shows little variability of the load, which leads to no adaptation to the training process, and increase the likelihood of illness and overtraining in players, and such a situation did not occur in players participating in our study.

Although we tried to have the same number of training sessions and compensation for all players during the season, this can be one of the limitations of the present study, since different number of games could affect the training workload. Another limitation of the study may be the lack of evaluation of external load monitoring with GPS [13,69]. It has been suggested that external load monitoring should be done in future studies.

5. Conclusions

The present study revealed that sprint performance improved throughout the season in young soccer players, with significant intra-season variations, especially in CWL and ACWR load variables (Eas and Mid). In addition, it was observed that maturation did not have a significant effect on the change in sprint performance. This study clearly showed that there could be a relationship between sprint performance and accumulated wokload variables, and that the significant change in sprint performance can be explained by load variables such as AWCR, TM, and TS. With the repetition of such studies, increasing the sample size in different ages and sports branches, along with taking into account different genders. As in this study, it was observed that in-season load optimization and adjustment of variability promoted sprinting performance increase, especially in young soccer players. This information can assist coaches in talent selection and optimal design and development of training programs for different workload variables throughout the competitive season period.

Author Contributions

Study Design—HN, HİC, EM-P. Data Collection—HN, HİC, SK, MEÖ. Data Analysis—HN, EM-P. Writing Original Draft—HİC, SK, MEÖ. Manuscript Review and Editing—HN, HİC, SK, MEÖ, EM-P. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

Players and their parents received a clear explanation of the study. Experimental procedures were approved by the Ethics Committee of the University of Mohaghegh Ardabili (09.03.2020) and the recommendations of Human Ethics in Research were followed according to the Helsinki Declaration. Written informed consent was obtained from both the players and their parents before beginning the investigation.

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Conflict of Interest

The authors declare no conflict of interest. HN and EM-P are serving as the Guest editors of this journal. We declare that HN and EM-P had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to AT.

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