

Article

Differences in External and Internal Load in Elite Youth Soccer Players within Different Match Timing Zones

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Abstract: The aim of this study was to determine and analyze the differences between the players' internal (IL) and external load (EL) in different time zones (T1: 0–45 min, T2: 45–70 min, T3: 0–70 min, T4: 70–90 min, T5: 45–90 min, and T6: 0–90 min) in elite youth soccer matches (U17–19 age category). The monitored group comprised elite youth soccer players ($n = 66$; age = 17.5 ± 1.2 years; body height = 178.5 ± 8.7 cm; body mass = 70.4 ± 6.3 kg). Multivariate analysis of variances was used to compare the following variables: relative total distance covered (TDC_{rel}), distance covered in different speed zones (Z1–Z6), high-metabolic load distance (HMLD), maximum running speed (S_{max}), number of acceleration (ACC) and deceleration (DCC) entries in different speed zones (Z1, Z2, Z3), and maximum heart rate (HR_{max}). Results revealed significant differences ($p < 0.05$) in the first 70 min (T3) compared to the last 20 min of the match (T4) in the following: TDC_{rel} was higher, up to 6.6% (123.09 ± 9.48 vs. 115.03 ± 9.42 m.min⁻¹); distance in Z5 (22.4%, 6.08 ± 1.82 vs. 4.72 ± 1.72 m.min⁻¹); Z4 (18.6%, 20.15 ± 4.82 vs. 16.40 ± 3.48 m.min⁻¹); Z3 (10.4%, 53.06 ± 47.52 m.min⁻¹); and HMLD (16.1%, 34.86 ± 5.67 vs. 29.26 ± 5.11 m.min⁻¹). We also found higher running performance in the first half (T1) than in the second half (T5) in the following parameters: TDC_{rel} , Z5, Z4, ACC_{Z1} , ACC_{Z2} , and DCC_{Z1} . With progressive time (in T4) we found a significant decrease in physical running performance, probably due to fatigue, which can lead to potential injury or losing in a match. The results of this study may provide helpful information in developing training strategies for coaches and in the set-up of plan for potential substitution of exhausted players mainly for the last 20 min of a match (T4). The present results are expressed as a relative value and should be compared with other study results with irregular timing zones.

Keywords: internal and external loads; elite youth soccer; GPS; match analysis; testing and diagnostic



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1. Introduction

A consistent finding in the literature is that soccer is becoming more physically demanding [1]. To be a successful player, it is necessary to enhance fitness level in practice, which, in turn, helps excel in a match situation [2,3]. Therefore, we want to maximize the elite players' fitness performance during the match by monitoring their load during the match. A study showed that 70% of professional players start their professional career at the age of 17–20 years [4]; however, there is a limited amount of research in this age category (elite performance level) to compare match load data and training data [5,6] or load data in the different time periods of a match [7].

Dellal et al. [8] reported that during a match, adult players reach greater external load (EL) such as sprinting distance than youth players (U17 category); however, Stevens et al. [9] noted no differences between elite adult players and youth players in covering the distances of the individual speed zones. In addition to the internal load (IL), younger players demonstrated greater amount of aerobic energy in locomotion activities, such as running and walking, than adult players during a match. Besides factors such as short length steps, high pace speed, and frequency relative to body size, it is possible that there is a greater relative physiological IL in young players than in adult players [10].

More than half of the total distance covered (TDC) comprised walking, jogging, and running $<14.4 \text{ km.h}^{-1}$ [11,12]. Relative total distance covered (TDC_{rel}) was $118.9 \pm 10.7 \text{ m.min}^{-1}$ and player's work-to-rest ratio was 2.1:1 [13]. In relation to the match's physical demand profile in the study by Gómez-Carmona et al. [14], the U18 players were monitored in terms of parameters such as TDC_{rel} , high intensity running (HIR), acceleration (ACC), deceleration (DCC), and average heart rate (HR_{avg}). This study reported that only 8–10% of TDC in a professional soccer game is covered with HIR ($>19.8 \text{ km.h}^{-1}$). Nevertheless, ACC is a more energetically demanding activity than moving at constant velocity [15] and repeated ability to accelerate and decelerate relative to their body mass from various velocities (rarely standing still) is a fundamental necessity for soccer players. Domene [16] reported that in the last period of the adult match (75–90 min), players covered a higher average distance with HIR than in the previous periods. Conversely, Mohr et al. [17] showed that in the last 15 min, HIR load showed a notable decrease compared to HIR load of the previous periods. Rampini et al. [12] also showed that the decrease in the TDC, HIR, and very high-intensity running (running speed $> 19.8 \text{ km.h}^{-1}$, VHIR) during the second half is not a systematic phenomenon and is associated with the amount of activity completed in the first half. Wehbe et al. [18] reported that when the team was winning, the average speed was lower by 4.17% than when the team was drawing. Randers et al. [19] found differences in covered HIR distance in the first 15 min period and less HIR distance covered during the last 15 min period, compared to all other 15 min intervals, with a reduction in HIR from the first to the last 15 min period of $46 \pm 19\%$, $37 \pm 26\%$, $50 \pm 26\%$, and $45 \pm 27\%$. The sprint distance during an official football match is only 1–4% [20]. The number of sprints, average sprint distance, and maximal sprint distance during the half time (45 min) were reported as 12.7 ± 6.1 , 18.2 ± 3.4 , and $35.1 \pm 11.3 \text{ m}$, respectively [21]. Players from the UEFA European League teams covered 167–345 m in sprints during the official match [22,23].

When monitoring heart rate (HR) for exercise intensity, there is a linear correlation between HR and oxygen consumption (VO_2) over varying submaximal loads [24]. Physiological requirements of soccer players were assessed by monitoring HR during the match [25]. Studies have found that the average exercise intensity for a professional soccer player is 80–90% of the HR_{max} [14,25]. Alexandre et al. [26] analyzed the HR zones during the official soccer matches of various performance levels. The intensity values were in the range of 80–90% HR_{max} and players spent up to 65% of the total match duration in this zone.

Using a new equipment like the global position system (GPS) to monitor players also helps build specific endurance in the season macro-cycle in the different youth categories. This significantly influences the players' performance at any position during a match [3,27] as well as helps by adding preventive fitness programs and analyzing each player's load on an individual basis [28].

We conducted our research to identify players' fitness profiles from both external and internal load points of view during official matches and to compare selected variables based on irregular time periods. The aim of this study was to determine and analyze the differences between the players' internal (IL) and external load (EL) in different zones (T1: 0–45 min, T2: 45–70 min, T3: 0–70 min, T4: 70–90 min, T5: 45–90 min, and T6: 0–90 min) in elite youth (U17 and U19 age category) soccer matches.

2. Materials and Methods

2.1. Subjects

The study cohort consisted of soccer players from the category of 17 years and under (U17) to 19 years and under (U19) teams who played a total of 90 min (min) during one of the 12 highest-level matches in the spring national season (February to May) 2019/2020 ($n = 66$; age = 17.5 ± 1.2 years; body height = 178.5 ± 8.7 cm; body mass = 70.4 ± 6.3 kg). The weekly micro-cycle at each of the matches was as follows: 5 soccer-specific trainings per week (90 min), one strength and power training (60 min), one official match (90 min), and one recovery day (day off). There was not a single joint or muscle injury during the testing. The training experience of the players was similar (>10 years of soccer-specific training). The players did not sustain any injuries during the measurement. Prior to measurement, participants were instructed on the course of measurement, the subsequent processing of results, and their potential use in scientific research. Measurements were performed according to the ethical standards of the Helsinki Declaration and the ethical standards in sport and exercise science research described by Harriss et al. [29].

2.2. GPS Data Collection

All the players were using a 15 Hz GPS (Spi HPU, GPSport®, Canberra, Australia) in championship matches. The only exception was the goalkeeper's game position, which was not included in the measurements. The GPS data were downloaded to the docking station and analyzed immediately after each match using GPSports Team AMS (GPSports®, Canberra, Australia). Additionally, we recorded players' heart rates using Polar T31 heart rate monitors (Polar Electro, Kempele, Finland). Subsequently, the data were exported to MS Excel, where basic statistical operations were performed.

2.3. Main Outcome Variables

The strategy used recently in monitoring the player's load during a match is to track and evaluate the TDC; TDC_{rel} ; distance/time ($m \cdot min^{-1}$); maximum running sprint speed (S_{max}) $km \cdot h^{-1}$; average speed during the match (S_{avg}) $km \cdot h^{-1}$; distance covered in different intensity speed zones: Z1 ($0-0.7 km \cdot h^{-1}$), Z2 ($0.7-7.2 km \cdot h^{-1}$), Z3 ($7.2-14.4 km \cdot h^{-1}$), Z4 ($14.4-19.8 km \cdot h^{-1}$), Z5 ($19.8-25.2 km \cdot h^{-1}$), Z6 ($>25.2 km \cdot h^{-1}$); high-metabolic load distance (HMLD); numbers of acceleration entries: ACC Z1-Z3 (ACC_{Z3} Very High Magnitude of Acceleration ($>3.6 m \cdot s^{-2}$), ACC_{Z2} High Magnitude of Acceleration ($2.4-3.6 m \cdot s^{-2}$), ACC_{Z1} Low Magnitude of Acceleration ($<2.4 m \cdot s^{-2}$)); and numbers of deceleration entries: DCC Z1-Z3 (DCC_{Z3} Very High Magnitude of Deceleration ($<-3.6 m \cdot s^{-2}$), DCC_{Z2} High Magnitude of Deceleration ($-2.4-3.6 m \cdot s^{-2}$), DCC_{Z1} Low Magnitude of Deceleration ($<-2.4 m \cdot s^{-2}$)), maximum heart rate (HR_{max}), average heart rate (HR_{avg}), and time spent in different intensity zones: HR_{Z1} steady state intensity (time in %), HR_{Z2} low intensity (%), HR_{Z3} aerobic intensity (%), HR_{Z4} submaximal intensity (%), HR_{Z5} maximum intensity (%). We applied parameters and criteria for player's load which has been used in previous research studies [1,7,23,30,31].

2.4. Statistical Analysis

We used descriptive and inductive statistics to process the data. Measurements were expressed using the arithmetic mean, and the measure of variability was expressed through standard deviation. Data normality was evaluated using the Shapiro–Wilk test. An outlier value was defined as if the data were found to be out of the interval of mean $\pm 2 \times$ standard deviation. The assumptions for using a parametric test were satisfied, and differences in the observed dependent variables between groups were assessed using a multivariate analysis of variance. Multiple comparisons of the mean of the monitored variables were performed using the Bonferroni's post hoc test. Moreover, the effect size coefficient was assessed using partial eta squared (η_p^2). For all analyses, the statistical significance level was set at $p < 0.05$. Radar charts were processed based on standardized values. Statistical analysis was performed using IBM® SPSS® v24 (Statistical Package for Social Science, Inc., Chicago, IL, USA).

3. Results

3.1. External Load

Results revealed significant differences for all indicators of EL during the observed match time period (Table 1, Figures 1 and 2). The players reached higher running performance in the first half than in the second half in the following observed indicators: TDC_{rel} was higher up to 6.6% (123.09 ± 9.48 vs. $115.03 \text{ m.min}^{-1}$); Z5 (22.4%, 6.08 ± 1.82 vs. $4.72 \pm 1.72 \text{ m.min}^{-1}$); Z4 (18.6%, 20.15 ± 4.82 vs. $16.40 \pm 3.48 \text{ m.min}^{-1}$); Z3 (10.4%, $53.06 \pm 47.52 \text{ m.min}^{-1}$); HMLD (16.1%, 34.86 ± 5.67 vs. $29.26 \pm 5.11 \text{ m.min}^{-1}$); S_{avg} (6.8%, 7.18 ± 0.56 vs. $6.59 \pm 0.60 \text{ km.h}^{-1}$); ACC_{Z1} (11.8%, 2.28 ± 0.54 vs. $2.01 \pm 0.55 \text{ n.min}^{-1}$); ACC_{Z2} (15.3%, 0.59 ± 0.24 vs. $0.50 \pm 0.26 \text{ n.min}^{-1}$); and DCC_{Z1} (11.8%, 1.69 ± 0.74 vs. $1.49 \pm 0.75 \text{ n.min}^{-1}$).

Table 1. Comparison of external load parameters of the different match time periods.

Parameters		T1	T2	T3	T4	T5	T6	F	p	η_p^2	Posthoc
		0–45	45–70	0–70	70–90	45–90	0–90				
TDC _{rel}	X	123.09	116.97	120.91	113.09	115.03	117.00	28.42	<0.05	0.3	a,b,c,d,e, f,j,k,l,n,o
(m.min ^{−1})	SD	9.48	11.09	8.89	12.01	9.42	9.02				
Z6	X	1.19	0.77	1.04	1.04	0.91	1.04	1.98	0.08	0.03	
(m.min ^{−1})	SD	1.82	2.17	1.59	1.98	3.45	1.48				
Z5	X	6.08	5.26	5.79	4.19	4.72	4.99	24.17	<0.05	0.27	c,d,e,g,h,i, j,k,l,m,n
(m.min ^{−1})	SD	1.82	2.17	1.59	1.98	1.72	1.48				
Z4	X	20.15	17.61	19.24	15.19	16.40	17.21	37.28	<0.05	0.37	a,b,c,d,e,f, g,h,j,k,l,m,n,o
(m.min ^{−1})	SD	4.82	4.17	4.05	4.33	3.48	3.50				
Z3	X	53.06	50.22	52.04	44.82	47.52	48.43	27.73	<0.05	0.3	c,d,e,g,h,j, k,l,m,n
(m.min ^{−1})	SD	7.66	8.20	6.63	9.33	7.26	6.75				
Z2	X	42.01	42.23	42.09	46.41	44.32	44.25	41.06	<0.05	0.39	c,d,e,g,h,i, j,k,l,m,n
(m.min ^{−1})	SD	3.47	4.25	3.01	5.21	4.02	3.82				
Z1	X	0.06	0.05	0.06	0.06	0.06	0.06	4.09	<0.05	0.06	h,i
(m.min ^{−1})	SD	0.03	0.03	0.02	0.03	0.02	0.02				
HMLD	X	34.86	31.00	33.41	27.50	29.26	30.46	56.54	<0.05	0.47	a,b,c,d,e,f, g,h,j,k,l,m,n,o
(m.min ^{−1})	SD	5.67	5.59	5.17	6.01	5.11	4.85				
S _{max}	X	28.40	26.93	28.77	26.74	27.90	28.96	32.77	<0.05	0.34	a,c,e,f,h,i, j,k,l,m,n,o
(km.h ^{−1})	SD	1.88	2.16	1.84	2.50	2.12	1.84				
S _{avg}	X	7.18	6.87	7.03	6.51	6.69	6.78	31.42	<0.05	0.33	a,b,c,d,e,f,g, h,j,k,l,m,n,o
(km.h ^{−1})	SD	0.56	0.65	0.55	0.77	0.60	0.55				
ACC _{Z1}	X	2.28	2.10	2.19	1.92	2.01	2.15	22.2	<0.05	0.26	a,b,c,d,e,g, h,j,k,m,n,o
(n.min ^{−1})	SD	0.54	0.52	0.49	0.67	0.55	0.51				
ACC _{Z2}	X	0.59	0.51	0.56	0.48	0.50	0.54	9.79	<0.05	0.13	c,d,e,j,k,l,n,o
(n.min ^{−1})	SD	0.24	0.27	0.23	0.27	0.26	0.23				
ACC _{Z3}	X	0.06	0.05	0.05	0.02	0.05	0.05	7.15	<0.05	0.10	c,j,n
(n.min ^{−1})	SD	0.08	0.08	0.07	0.02	0.07	0.07				
DCC _{Z1}	X	1.69	1.52	1.63	1.45	1.49	1.59	18.92	<0.05	0.23	a,b,c,d,e, f,j,k,l,n,o
(n.min ^{−1})	SD	0.74	0.76	0.72	0.78	0.75	0.73				
DCC _{Z2}	X	0.52	0.50	0.51	0.45	0.47	0.50	4.48	<0.05	0.06	c
(n.min ^{−1})	SD	0.26	0.25	0.24	0.34	0.27	0.25				
DCC _{Z3}	X	0.14	0.14	0.13	0.10	0.12	0.12	5.08	<0.05	0.07	c
(n.min ^{−1})	SD	0.13	0.12	0.11	0.09	0.10	0.10				

Note: Relative total distance covered (TDC_{rel}), maximum sprint speed (S_{max}), average speed (S_{avg}), relative distance covered in different speed zones Z1 (0–0.7 km.h^{−1}), Z2 (0.7–7.2 km.h^{−1}), Z3 (7.2–14.4 km.h^{−1}), Z4 (14.4–19.8 km.h^{−1}), Z5 (19.8–25.2 km.h^{−1}), Z6 (>25.2 km.h^{−1}), high-metabolic load distance (HMLD); number of acceleration entries: ACC_{Z3} (Very High Magnitude of Acceleration (>3.6 m.s^{−2}); ACC_{Z2} High Magnitude Acceleration (2.4–3.6 m.s^{−2}), ACC_{Z1} Low Magnitude of Acceleration (<2.4 m.s^{−2}), numbers of deceleration entries: DCC_{Z3} Very High Magnitude of Deceleration (<−3.6 m.s^{−2}), DCC_{Z2} High Magnitude of Deceleration (−2.4–3.6 m.s^{−2}), DCC_{Z1} Low Magnitude of Deceleration Distance (<−2.4 m.s^{−2}); a—significant difference between T1 and T2; b—significant difference between T1 and T3; c—significant difference between T1 and T4; d—significant difference between T1 and T5; e—significant difference between T1 and T6; f—significant difference between T2 and T3; g—significant difference between T2 and T4; h—significant difference between T2 and T5; i—significant difference between T2 and T6; j—significant difference between T3 and T4; k—significant difference between T3 and T5; l—significant difference between T3 and T6; m—significant difference between T4 and T5; n—significant difference between T4 and T6; o—significant difference between T5 and T6.

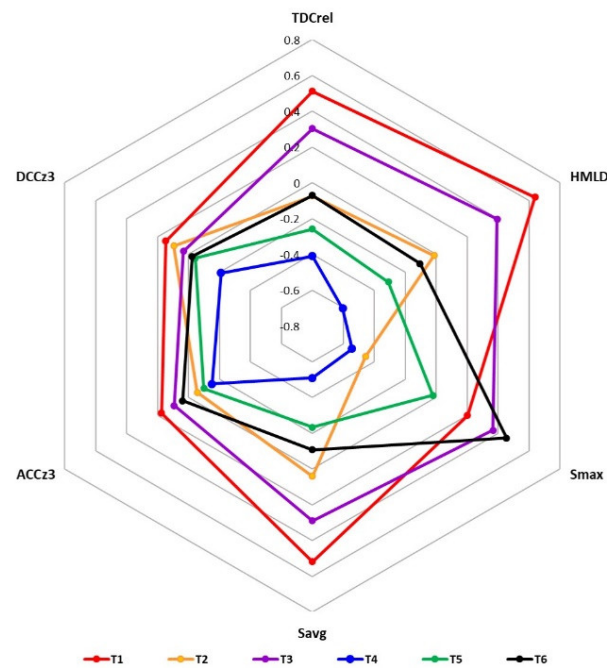


Figure 1. Comparison of selected external load parameters within different match timing zones. Note: TDCrel: relative total distance covered; HMLD: high-metabolic load distance; Smax: maximum sprint speed; Savg: average speed; ACCz3: number of acceleration entries ($>3.6 \text{ m.s}^{-2}$); DCCz3: number of deceleration entries ($<-3.6 \text{ m.s}^{-2}$); T1: 0–45 min; T2: 45–70 min; T3: 0–70 min; T4: 79–90 min; T5: 45–90 min; T6: 0–90 min.

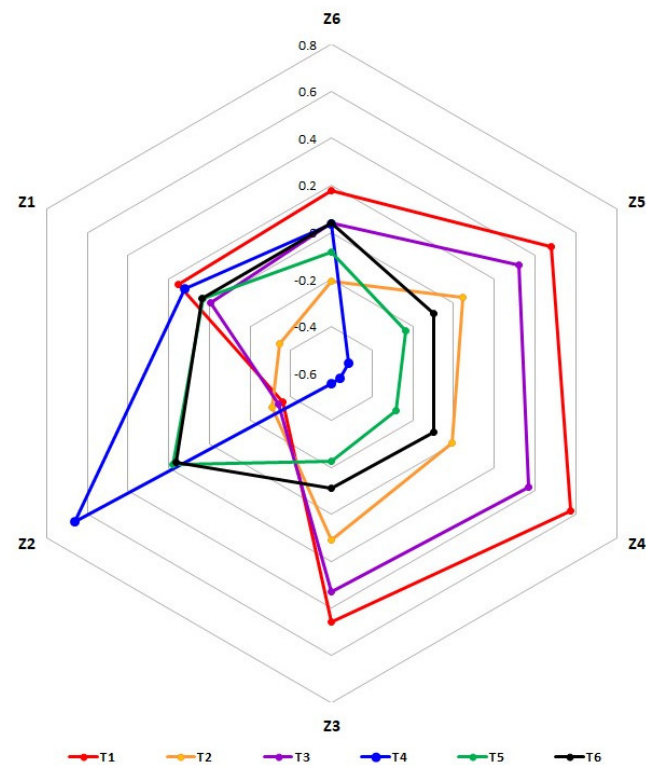


Figure 2. Comparison of distance covered in speed zones within different match timing zones. Note: Z1: 0–0.7 km.h^{-1} ; Z2: 0.7–7.2 km.h^{-1} ; Z3: 7.2–14.4 km.h^{-1} ; Z4: 14.4–19.8 km.h^{-1} ; Z5: 19.8–25.2 km.h^{-1} ; Z6: $>25.2 \text{ km.h}^{-1}$; T1: 0–45 min; T2: 45–70 min; T3: 0–70 min; T4: 79–90 min; T5: 45–90 min; T6: 0–90 min.

Conversely, in the second half, we found a significant increase in the running distance covered in Z2 (5.21%, 42.01 ± 3.47 vs. 44.32 ± 4.02 m.min⁻¹).

The analysis detected significant differences between the first 70 min (T3) compared to the last 20 min of the match (T4) in the following external performance indicators: higher TDC_{rel} in T3 than in T4 (6.5%, 120.91 ± 8.89 vs. 113.09 ± 12.01 m.min⁻¹); Z5 (27.6%, 5.79 ± 4.19 m.min⁻¹); Z4 (21.1%, 19.24 ± 4.05 vs. 15.19 ± 4.33 m.min⁻¹); Z3 (13.9%, 52.04 ± 6.63 vs. 44.82 ± 9.33 m.min⁻¹); HMLD (17.7%, 33.41 ± 5.17 vs. 27.50 ± 6.01 m.min⁻¹); S_{max} (7.1%, 28.77 ± 1.84 vs. 26.74 ± 2.50 km.h⁻¹); S_{avg} (7.4%, 7.03 ± 0.55 vs. 6.51 ± 0.77 km.h⁻¹); ACC_{Z1} (12.3%, 2.19 ± 0.49 vs. 1.92 ± 0.67 n.min⁻¹); ACC_{Z2} (14.3%, 0.56 ± 0.23 vs. 0.48 ± 0.27 n.min⁻¹); ACC_{Z3} (60.0%, 0.05 ± 0.07 vs. 0.02 ± 0.02 n.min⁻¹); and DCC_{Z1} (11.0%, 1.63 ± 0.72 vs. 1.45 ± 0.78 n.min⁻¹). On the other hand, the study found lower distance covered in T3 than in T4 for Z2 (9.3%, 42.09 ± 3.01 vs. 46.41 ± 5.21 m.min⁻¹).

3.2. Internal Load

Results revealed significant differences in HR_{max} during the time of the match, particularly comparing the first half with the last stage (T4) of the match (Table 2). During the second half, the players had significantly lower HR_{avg} than that during the first half. While there were no significant differences in time (HR_{Z3}, HR_{Z4}) in highest intensity (HR_{Z5}), we noted significantly lower internal load in the second half. During the second half, we did not find differences between T2 (45–70 min) and T4 (70–90 min).

Table 2. Comparison of internal load parameters of the different match time periods.

Parameters		T1	T2	T3	T4	T5	T6	F	p	η_p^2	Posthoc
		0–45	45–70	0–70	70–90	45–90	0–90				
HR _{max} (beats.min ⁻¹)	X	192.70	188.74	193.23	187.48	188.11	193.76	57.45	<0.05	0.47	a,c,d,f, i,j,k,n,o
	SD	6.57	6.58	6.40	6.61	5.97	6.05				
HR _{avg} (beats.min ⁻¹)	X	168.41	163.85	166.62	164.53	164.19	165.58	8.23	<0.05	0.11	a,d,f,k,o
	SD	12.38	10.06	9.36	9.92	9.12	8.73				
Time in HR _{Z1} (%)	X	18.80	25.92	22.36	24.48	25.20	23.42	4.66	<0.05	0.07	a,b,o
	SD	2.01	4.65	2.80	4.62	3.95	3.29				
Time in HR _{Z2} (%)	X	18.80	25.92	22.36	24.48	25.20	23.42	6.33	<0.05	0.09	a,b,d,e,f,o
	SD	16.47	17.34	15.27	17.16	15.09	14.03				
Time in HR _{Z3} (%)	X	19.29	21.93	20.62	23.56	22.75	22.09	5.28	<0.05	0.08	
	SD	10.18	9.43	8.43	9.96	8.25	7.65				
Time in HR _{Z4} (%)	X	22.79	24.97	23.89	28.02	26.50	25.96	5.03	<0.05	0.07	
	SD	10.38	11.67	9.48	17.17	13.28	12.07				
Time in HR _{Z5} (%)	X	34.53	19.57	27.05	17.85	18.71	22.45	26.82	<0.05	0.29	a,b,c,d,e, f,j,k,l,n,o
	SD	25.63	17.40	19.47	14.89	14.57	14.86				

Note: HR_{max}: maximum heart rate, (beats.min⁻¹), HR_{avg}: average heart rate (beats.min⁻¹), time spent in different intensities zones (Z1–Z5), time in HR_{Z1}: steady state intensity (%), time in HR_{Z2}: low intensity (%), time in HR_{Z3}: aerobic intensity (%), time in HR_{Z4}: submaximal intensity (%), time in HR_{Z5}: maximum intensity (%); a—difference between T1 and T2; b—significant difference between T1 and T3; c—significant difference between T1 and T4; d—significant difference between T1 and T5; e—significant difference between T1 and T6; f—significant difference between T2 and T3; g—significant difference between T2 and T4; h—significant difference between T2 and T5; i—significant difference between T2 and T6; j—significant difference between T3 and T4; k—significant difference between T3 and T5; l—significant difference between T3 and T6; m—significant difference between T4 and T5; n—significant difference between T4 and T6; o—significant difference between T5 and T6.

4. Discussion

In this study, we aimed to determine IL and EL (expressed in relative values) and set-up irregular timing zones (T1: 0–45 min, T2: 45–70 min, T3: 0–70 min, T4: 70–90 min, T5: 45–90 min, and T6: 0–90 min) for elite youth (U17 and U19 age category) soccer matches. Significant differences were noted between the observed match time period for

all EL and IL (Table 1, Table 2). Players reached higher TDC_{rel} by 6.6% (123.09 ± 9.48 vs. $115.03 \text{ m} \cdot \text{min}^{-1}$) in the first half than in the second half. There was a relatively large difference (up to 22.4%) for the first half's distance, spent in Z3 ($>14.4 \text{ km} \cdot \text{h}^{-1}$), while for the second half (T5; 45–90 min), only the distance in the Z2 ($0.7\text{--}7.2 \text{ km} \cdot \text{h}^{-1}$) was increased by 5.21%. Youth, especially elite youth, were chosen because of the limited research in the area of comparative profiles of the match demands in adolescent team sports [32,33]. Other studies [3,12,34,35] evaluated comparable factors of movement using the GPS system; however, the study subjects in the study were adult elite soccer players. Additionally, soccer analysis using the GPS also deviates from the elite sphere; covered distance in semi-pro players varies at $113.0 \pm 8.9 \text{ m} \cdot \text{min}^{-1}$ [36]. In a study conducted by Rampinini et al. [12], significant correlation between TDC ($r = 0.62$, $p < 0.001$, $CI_{95\%} = 0.36\text{--}0.79$), HIR ($r = 0.51$, $p < 0.05$, $CI = 0.21\text{--}0.72$), and VHIR ($r = 0.65$, $p < 0.001$, $CI_{95\%} = 0.40\text{--}0.81$) was established. In top-level European and Australian leagues, Sarmiento et al. [34] reported TDC from 10,063 to 11,230 m. Varley et al. [35] reported $104 \pm 10 \text{ m} \cdot \text{min}^{-1}$ for the Australian soccer players. We must emphasize that there is a significant difference in soccer formation such as 4-3-3, 4-4-2, and 4-5-1 gameplay, which might have influenced the player load [11]. Buchheit et al. [37] revealed that in addition to age, maturation and body dimension were position-dependent variables that influenced in-match running performance. Demoupoulos [38] reported greater TDC in the U16 category than in the U18 category. TDC was significantly greater in the U16 team for both half times (1st half: $5.2 \pm 0.6 \text{ km}$; 2nd half: $4.9 \pm 0.4 \text{ km}$) than in the U18 (1st half: $4.8 \pm 0.6 \text{ km}$, $ES = 0.70$, $CI_{95\%} = 0.01\text{--}0.83$; 2nd half: $4.5 \pm 0.5 \text{ km}$, $ES = 0.74$, $CI_{95\%} = 0.04\text{--}0.7$, $p < 0.001$) and U21 teams (1st half: $4.7 \pm 0.6 \text{ km}$, $p < 0.001$, $ES = 0.74$, $CI_{95\%} = 0.05\text{--}0.91$; 2nd half: $4.5 \pm 0.7 \text{ km}$, $p < 0.004$, $ES = 0.55$, $CI_{95\%} = -0.08\text{--}0.76$).

In relation to the match demand profile, Gómez-Carmona et al. [14] examined U18 players, using parameters such as TDC_{rel} $98.3 \pm 21.94 \text{ m} \cdot \text{min}^{-1}$ at an average speed of $5.95 \pm 0.94 \text{ km} \cdot \text{h}^{-1}$ and with $9.74 \pm 4.21\%$ HIR. The range of the TDC_{rel} was 93.5 to $108.8 \text{ m} \cdot \text{min}^{-1}$. Barron et al. [39] used GPS units to monitor distances covered by players (U18) in ACC and DCC zones. From a time point of view, the study monitored the decline in ACC/DCC (-4.0 to $4.0 \text{ m} \cdot \text{s}^{-2}$) between the first and second halves. In our study, we also found a significant decline in ACC/DCC numbers of entries between the two halves; for ACC_{Z2} ($2.4\text{--}3.6 \text{ m} \cdot \text{s}^{-2}$) by 14.3%; ACC_{Z3} ($>3.6 \text{ m} \cdot \text{s}^{-2}$) by 60.0%; and DCC_{Z1} ($<-2.4 \text{ m} \cdot \text{s}^{-2}$) by 11.0% in between T3 and T4 (0–70 vs. 70–90 min). We must emphasize that it is difficult to compare the ACC data of our study with those of other studies as there is little consensus regarding the use of ACC thresholds in team sports [40]. Our study and the study by Barron et al. [39] suggest that high speed movements in the first half reach a volume when enough neuromuscular fatigue accumulates, influencing performance in the latter half of the match (45–90 min or even 70–90 min). The negative impact of neuromuscular fatigue and strength imbalances on specific soccer skills has been also reported [41]. Demopoulos [38] revealed significantly greater TDC_{rel} for the U16 group ($108.68 \pm 9.79 \text{ m} \cdot \text{min}^{-1}$) than for the U18 ($99.97 \pm 11.18 \text{ m} \cdot \text{min}^{-1}$) and U21 ($98.72 \pm 14.04 \text{ m} \cdot \text{min}^{-1}$) groups. In our research, we established TDC_{rel} to be $117 \pm 9.02 \text{ m} \cdot \text{min}^{-1}$ for the total match duration (0–90 min). The players reached in the first half higher TDC_{rel} , up to 6.6%, than in the second half (123.09 ± 9.48 vs. $115.03 \pm 9.42 \text{ m} \cdot \text{min}^{-1}$). Further analysis also revealed significant differences between the first 70 min (T3; Table 1, Figure 2) and the last 20 min of the match in terms of Z5 (27.6%, $5.79 \pm 4.19 \text{ m} \cdot \text{min}^{-1}$), Z4 (21.1%, 19.24 ± 4.05 vs. $15.19 \pm 4.33 \text{ m} \cdot \text{min}^{-1}$), and Z3 (13.9%, 52.04 ± 6.63 vs. $44.82 \pm 9.33 \text{ m} \cdot \text{min}^{-1}$). Here, we identify the possibility of focusing on soccer-specific speed-endurance training while practicing using small-sided games. This strategy could help increase the players' fitness levels, improve their physical preparation to last for the total match duration, and avoid the decrease in running performance towards the end of the match.

The tactical gameplay of the team could also change the high intensity running and sprinting distance ($\sim 30\%$) [12,42]. There is also significant difference between the playing positions in terms of very high intensity running distance ($>19.8 \text{ km} \cdot \text{h}^{-1}$), jogging and running ($7.2\text{--}19.7 \text{ km} \cdot \text{h}^{-1}$), Z5, ACC, and DCC entries. Previous studies [18,43] reported that

attackers performed 27.5% and 30.24% less medium acceleration entries than defenders and midfielders, respectively ($p < 0.01$; $d = 1.54$ and 1.73). In our study, we found ACC_{Z1} (11.8%, 2.28 ± 0.54 vs. 2.01 ± 0.55 n.m⁻¹), ACC_{Z2} (15.3%, 0.59 ± 0.24 vs. 0.50 ± 0.26 n.min⁻¹), and DCC_{Z1} (11.8%, 1.69 ± 0.74 vs. 1.49 ± 0.75 n.min⁻¹). A higher running performance (Table 1) in the first half than that in the second half is an important finding of our research. The quality of the opponent's team (best and worst opponents) should also be considered, as it might have affected the distance covered in different speed zones [12,44]. In the last period (75–90 min), Domene [16] found higher HIR than that in the previous periods of time, which contradicts our study findings. During a typical match, there is a significant difference in distance covered with HIR (from 3138 ± 565 to 1834 ± 256 m, $p < 0.01$). Bradley [23] reported up to 36% difference in HIR. Additionally, detailed motion analysis combined with use of the triaxial accelerometer was performed by Dalen et al. [44]. They evaluated a full elite match by first and second half performances. The average number of ACC entries for the first and second halves was 38 ± 12 and 37 ± 12 , respectively, with no statistical difference; their novel finding was that ACC covered up to 10% of the player load with load differences of 7–17% ($p < 0.09$). They also enrolled a remarkably high number of participants ($n = 298$) at each position, but the participants were adults (age = 25.38 ± 4.73 years).

We found differences in speed variables between the first 70 min and the last 20 min of the match in speed zones. S_{max} differed by 7.1% (from 28.77 ± 1.84 to 26.74 ± 2.50 km.h⁻¹) and S_{avg} differed by 7.4%. We also found significant differences in S_{avg} (6.8%, 7.18 ± 0.56 vs. 6.59 ± 0.60 km.h⁻¹) between the first and second halves. In the last period (70–90 min), we evaluated only 1.04 m.min⁻¹ sprint distance covered by players, which is the lowest number of sprints within the entire match. In the U19 category, Reinhart et al. [15] revealed large differences in sprint times ($d = -2.5$), but the ACC.min⁻¹ between 5 and 20 km.h⁻¹ as well as 20 and 25 km.h⁻¹ showed merely small variations ($d < 0.5$). According to Stevens et al. [45], during an official soccer match, the sprint distance in Dutch team pro players was ~281 m, while it varied between 100 and 190 m in English team pro players [46,47]. We reported ~90 m sprint distance for elite youth players in our study. In terms of the IL, we found differences between the T1 and T5. In the second half, the players had significantly lower HR_{avg} than during the first half. A very common parameter while monitoring player load is the HR variability [25,48,49]. The highest player load in high-intensity anaerobic threshold was found in central midfielders ($21.8 \pm 7.8\%$) and attackers ($17.8 \pm 3.8\%$). The most significant decrease in high intensity was observed in the last 15 min of the match [50,51]. Elite youth players in our study spent 27% of time in HR_{Z5} during the first 70 min, compared to 18% of the time in the last 20 min of the match, which is similar to the results of Mohr et al. [50] and Rienzi et al. [51]. Bujnovsky et al. [52] reported that in the second half, the HR of elite adult players decreased by 9 bpm; we observed a 4 bpm decrease in our study. This decrease is attributed most probably to fatigue.

There is an increased interest to maintain a balance between the player load during a match and the recovery status to maximize the supercompensation and player performance while minimizing the risk of injury [53,54]. Price et al. [55] reported that 36% of the injuries during a match occur in the last third of each half. Therefore, we believe that future research should investigate the injury ratio during elite soccer matches and evaluate the differences between the physical load in chosen periods. We observed a significant difference ($p < 0.05$) between the first 70 min (T3) and last 20 min of the match (T4) in several parameters: TDC_{rel} , Z5, Z4, and Z3 zones. We also encountered a higher running performance in the first half than in the second half in the following observed indicators: TDC_{rel} , Z5, Z4, ACC_{Z1} , ACC_{Z2} , and DCC_{Z1} . However, our study has several limitations. The monitoring of match load took place during the spring season 2019/20 in the elite youth soccer league of the Czech Republic. This data may not be generalizable to recreational level soccer players. Additionally, the opposing team level varied. In addition, we could not take situational variables into account (winning, drawing, and losing), which often determined how hard each player needed to play in a game of soccer. Some of the measurements were obtained

when playing against worse opponents than expected. The tactical gameplay of the team was from the beginning of the match 4-4-2, but changed occasionally because of the actual match result. It would be beneficial if more teams of the first Czech division are evaluated, or the elite youth players are compared with those of international teams in the same age category. We aim to compare league and international level matches as well as focus more on the differences in playing positions in our future study.

5. Conclusions

This study determined the difference between external and internal load in several time parameters (T1: 0–45 min, T2: 45–70 min, T3: 0–70 min, T4: 70–90 min, T5: 45–90 min, and T6: 0–90 min) of elite youth (U17 and U19 age category) soccer matches with GPS running performance and HR response. The main findings were observed in both EL and IL parameters between the first 70 min (T3) and the last 20 min of the match (T4), and between the first half (T1) and the second half (T5). A decrease in HMLD in the last T4 was up to 17.7% compared to T3. Moreover, players' performances in highest heart rate zone (HR_{Z5}) in T4 phase was just 17.85% compared to 27.05% in the T3 phase. Because of these facts, we must implement soccer-specific training of small sided and large games to be able maintain high intensity performance during the total match duration. On-field demands, specific player load, and youth physiological adaptability to the soccer match are the most important determinants for setting up a soccer training strategy. Factual results of players' loads are the basis for designing team, group, and individual training programs in all team-based sports. Monitoring of the player's load could also give us the opportunity to improve the aerobic and anaerobic capacity at the start of the youth elite player's season and to get progressive results at the end of the season macro-cycle. The present study may enhance the process of training and help improve players' fitness levels. Furthermore, it could be beneficial for improving individual player monitoring during matches and, thus, help substitute faster players who do not fit in the tactical play and help change the play. Our data could also be beneficial when comparing youth players to professionals, in situations such as young players graduating to their club's first-team squad.

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