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WORKLOADS OF YOUNG SOCCER PLAYERS

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Abstract. *The purpose of this study is to present a comparison of the workload demonstrated by young soccer players during the phases of warm-up (WU), first half (FH) and second half (SH) of a league match. Eleven young Polish soccer players took part in this research, playing a league match after completing the WU. During the WU, FH and SH of the match the following variables were recorded: total distance run, maximal and average speed achieved during the runs, number of sprints, distances run in the different speed zones, durations of increased heart rate (HR) in specific ranges, and the maximal, mean and minimal HR. The variables were recorded by means of the Global Positioning System (GPS). The research showed that there were significant differences between the WU, FH and SH in the total distances run (F=30.107, p<0.001), the average speed achieved during the runs (F=37.731, p<0.001), the distances run at different speeds (p<0.001), the duration of increased HR in specific zones, and HRmean (p=0.002) and HRmin (p<0.001). Post hoc analysis confirmed that, for the majority of the analyzed parameters, the WU provided a smaller load for the body than did the FH or SH, the intensity of which in some part was higher than that encountered at the anaerobic threshold. In conclusion, it has been shown that the WU and the two halves of the match load the body to varying degrees, the former doing so to a lesser extent than FH or SH.*
Keywords: *heart rate, running load, soccer.*

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Introduction

Previous studies using computer software for recording physical activity and physiological responses to soccer players' workloads during training and matches have determined that the distances run by a high-class soccer player during a soccer game can vary from 9 to13 kilometers. However, it is covered at a level of low-intensity effort, using the relatively small amounts of energy required for walking or jogging (Rampinini et al., 2007). A high-intensity run (sprint) occurs less frequently (Di Salvo et al., 2010). However, the number of runs at a high-intensity loading (around 24 km/h) differs significantly between the initial and final parts of the match (Bradley et al., 2009). A single sprint usually lasts no longer than 5 seconds (Andrzejewski et al., 2013). When matches are being won, central defenders perform fewer sprints and the forwards perform significantly more, compared to matches that are being lost (Bradley et al., 2013). The ability to perform at and sustain a level of high intensity effort is a distinguishing characteristic of players in terms of their physical performance during match conditions. On the other hand, it has been observed that having better technical skills means that the distance covered at high intensity or in a sprint becomes smaller (Di Salvo et al., 2009). A similar relationship was observed by Bradley, Noakes et al. (2013), who showed that soccer players of the worst-ranked teams (relegated to a lower division for the next season) covered during matches a greater distance at the level of high-intensity effort than players of the best-ranked teams (promoted to a higher division for the next season), despite the fact that their physical condition was similar. Rampinini et al. (2007) observed increased running activity of a professional soccer team in matches against better opponents.

An important indicator characterizing the match activity of soccer players, apart from the variation in distances run at different speeds, is heart rate (HR). Analyzing the workloads of young players, Capranica et al. (2001) observed that during 85 % of a match HR fluctuated within 170 bpm. The players' workload should theoretically be similar in both halves of a match and to this element of the physical stresses of a match researchers have attached a lot of importance. Relatively less attention from the research point of view has been attached to the pre-match warm-up (WU); it is also the case that coaches and players themselves do not always pay enough attention to this part of competitive sport preparation. Most frequently the WU is considered to be an element of anti-traumatic prophylaxis (Pilis et al., 2017), and its versatile potential for preparing the body for the coming loads of a submaximal, maximal and supramaximal intensity is forgotten (Sander et al., 2013). However, as an example of thinking more creatively about the WU, it has been found that using the Pilates program during a WU may improve muscular balance and correct the body posture of athletes (Horbacz et al., 2013). The above data was collected by numerous authors using technologically advanced devices that are at the beginning to be widely available and that is why it is possible to register training loads even in smaller soccer centers and also among young soccer players.

Recognizing the importance of both the warm-up and the main part of the match, the present study was constructed to compare the running load and body response in terms of heart rate of young soccer players during the warm-up, first and second halves of a league match.

Material and Methods

Eleven young Polish soccer players (18.03±0.27 years; 69.15±4.72 kg; 177.61±4.96 cm), members of the central professional juniors' league, participated in the study. Recording of the somatic workload was conducted during the warm-up (WU), first half (FH) and second half (SH) of a match. The WU was performed in such a way that its duration was equivalent to either half of a match, with static and stretching exercises in the first stage, after which running exercises of increasing intensity were introduced. During the WU, FH and SH the following variables were recorded: total distance run, maximal and average speed during the runs, number of sprints, distances run at different speeds, durations of effort at specific HR zones, and maximal, average and minimal HR values, both absolute and relative. The durations of effort at specific HRs were recorded in five ranges (zones): (I) 50-59 % HRmax; (II) 60-69 % HRmax; (III) 70-79 % HRmax; (IV) 80-89 % HRmax; (V) 90-100 % HRmax. The distances covered were also recorded in five speed run ranges (zones): (1) 3.00-6.99 km/h; (2) 7.00-10.99 km/h; (3) 11.00-14.99 km/h; (4) 15.00-18.99 km/h; (5) 19.00 km/h and above. The recording of these parameters was made possible by using the Global Positioning System (GPS, Polar Team Pro Finland - Sensor GPS (10Hz), MEMS Motion Sensor (200 Hz), which was attached to the skin of each player's chest. The parameters were read using Polar Team Pro.

The study was conducted with the permission nr KB-1/2013 of Ethical Committee of Jan Długosz University in Częstochowa.

The arithmetic means and standard deviations were calculated in order to provide a statistical description of the data. Then one-way analysis of variance with repeated measurements and Bonferroni test post hoc analysis was used. Statistically significant values were taken as $p<0.05$.

Results

Numerical data characterizing the running loads and the circulatory system reactions occurring during the WU, FH and SH are presented in Tables 1, 2 and 3 respectively.

Table 1 **Values of variables describing the warm-up**

Variables	**Match phase: Warm-up**				
	Mean	***Median***	***Stan. Dev.***	***Skewness***	***Kurtosis***
HRmin [bpm]	77.91	84	18.02	-1.28375	0.60183
HRmean [bpm]	136.64	140	10.69	-0.4977	-0.5775
HRmax [bpm]	186.55	187	12.72	0.75817	0.92533
HRmin [%]	39.18	42	8.92	-1.24824	0.52585
HRmean [%]	68.46	70	5.35	-0.4275	-0.63759
HRmax [%]	93.55	94	6.36	0.67023	0.67643
HR duration in zone I [s]	516.09	504	242.97	0.09315	-0.42657
HR duration in zone II [s]	832.64	844	247.64	0.01127	-0.97232
HR duration in zone III [s]	832.82	852	234.57	0.05565	0.04418
HR duration in zone IV [s]	476.55	362	349.41	0.66699	-0.93809
HR duration in zone V [s]	47.09	47	50.11	0.41709	-1.57529
Total distance [m]	2663.73	2746	192.39	-1.50998	2.42628
Maximal speed [km/h]	27.91	29.22	4.19	-1.02232	0.26079
Average speed [km/h]	3.52	3.6	0.21	-1.10058	0.55746
Sprints [number]	11.91	11	3.91	0.85588	3.03901
Distance covered in zone 1 [m]	1295.55	1302	61.81	-0.05929	-1.12299
Distance covered in zone 2 [m]	650.82	620	110.25	0.60156	0.59812
Distance covered in zone 3 [m]	330.18	360	106.95	-1.00286	0.25524
Distance covered in zone 4 [m]	87.55	76	44.59	0.66274	1.61029
Distance covered in zone 5 [m]	46.55	48	30.96	0.4868	-0.00378

The arithmetic mean values of the tested variables obtained in Table 1 indicate a significant load of the tested athletes and the changes in skewness and kurtosis are relatively small.

The values of arithmetic means of the variables examined in Table 2 indicate the maximum load of the tested athletes and the changes in the skewness and kurtosis value are in some cases significant.

Table 2 **Values of variables describing the first half of the match**

Variables	**Match phase: First half**				
	Mean	***Median***	***Stan. Dev.***	***Skewness***	***Kurtosis***
HRmin [bpm]	117.46	120	18.69	-0.03711	-2.15061
HRmean [bpm]	169.46	172	15.15	-2.08301	5.55417
HRmax [bpm]	192.18	195	11.06	-1.36036	3.48776
HRmin [%]	59	60	9.25	-0.00185	-2.13001
HRmean [%]	85	86	7.51	-2.05337	5.46546
HRmax [%]	96.36	98	5.41	-1.43956	3.5427
HR duration in zone I [s]	51.46	0	163.72	3.31457	10.99004
HR duration in zone II [s]	247.82	71	538.79	3.13859	10.09674
HR duration in zone III [s]	424.18	314	261.42	0.73803	-0.97576
HR duration in zone IV [s]	1141.82	1287	545.45	-0.79256	0.20847
HR duration in zone V [s]	1008.27	983	655.45	0.36922	0.1606
Total distance [m]	5324.09	5626	1066.20	-1.80025	4.11438
Maximal speed [km/h]	27.80	28.59	4.23	-1.5696	3.66956
Average speed [km/h]	6.931	7.34	1.37	-1.80534	4.06507
Sprints [number]	13.18	11	8.29	0.7521	0.01532
Distance covered in zone 1 [m]	1667	1635	105.23	0.1049	-1.6085
Distance covered in zone 2 [m]	1208.82	1237	353.90	-0.97266	2.09908
Distance covered in zone 3 [m]	1209.46	1202	452.43	-1.27427	2.79522
Distance covered in zone 4 [m]	632.73	647	286.99	-0.73714	1.35176
Distance covered in zone 5 [m]	393.27	353	231.61	-0.03423	-0.83874

The arithmetic mean values of the analyzed variables of athletes examined in Table 3 reach the maximum level, and especially kurtosis are in a few cases large.

It was shown that during the WU, FH and SH the soccer players ran different distances ($F=30.107$; $p<0.001$), and that the distances were significantly shorter during the WU than during the FH and SH ($p<0.001$); furthermore, during the FH a longer distance was run than during the SH ($p=0.050$). There was also a significant difference between the three analyzed exercise phases in terms of average running speed ($F=37.731$; $p<0.001$), as shown in Table 4.

Table 3 **Values of variables describing the second half of the match**

Variables	Match phase: Second half				
	Mean	***Median***	***Stan. Dev.***	***Skewness***	***Kurtosis***
HRmin [bpm]	94.18	100	30.73	-1.60685	3.27132
HRmean [bpm]	161.92	167	13.36	-2.08747	4.68445
HRmax [bpm]	190.18	190	9.00	-0.81464	1.83227
HRmin [%]	47.36	50	15.39	-1.639	3.40372
HRmean [%]	81.18	84	6.66	-2.00529	4.29906
HRmax [%]	95.18	95	4.47	-0.8947	2.09274
HR duration in zone I [s]	124.55	19	314.96	3.2522	10.68042
HR duration in zone II [s]	329.91	173	420.34	2.13754	4.08696
HR duration in zone III [s]	599.18	464	317.50	0.50499	-1.05218
HR duration in zone IV [s]	1055.36	979	486.12	-0.48071	1.11293
HR duration in zone V [s]	531.18	484	393.082	0.08998	-1.14405
Total distance [m]	4412.55	4878	1177.45	-0.89711	-0.545
Maximal speed [km/h]	29.10	29.83	4.26	-1.27626	3.38009
Average speed [km/h]	6.26	6.47	1.23	-1.62222	4.04082
Sprints [number]	11.18	11	5.06	-0.29456	-0.93825
Distance covered in zone 1 [m]	1539	1689	448.99	-0.7554	-0.27726
Distance covered in zone 2 [m]	921.27	964	340.89	0.27795	0.42854
Distance covered in zone 3 [m]	897.91	978	353.85	-0.86279	0.00585
Distance covered in zone 4 [m]	463.91	477	186.72	-0.90954	1.50229
Distance covered in zone 5 [m]	368.36	352	192.15	-0.35291	-0.15973

Table 4 **Statistical analysis of variables characterizing sprints**

Parameters	Analysis of variance	Post hoc analysis		
		1vs2	***1vs3***	***2vs3***
Total distance [m]	F=30.107; p<0.001	p<0.001	p<0.001	p=0.050
Maximal speed [km/h]	F=1.1227; p=0.345	NS	NS	NS
Mean speed [km/h]	F=37.731; p<0.001	p<0.001	p<0.001	NS
Sprints [number]	F=0.397; p=0.677	NS	NS	NS

NS – non-significant

The data in Table 5 show that the soccer players ran significantly different distances in all the above described speed run zones in the three exercise phases (p<0.001), and that during the WU the distances were shorter than during the FH and also the SH (all zones except 3.00-6.99 km/h). In addition, at the speed run zones of 7.00-10.99 km/h and 11.00-14.99 km/h, athletes ran longer distances during the FH than during the SH.

Table 5 **Statistical analysis of the distances covered at different speeds**

Parameters	Analysis of variance	Post hoc analysis		
		1vs2	***1vs3***	***2vs3***
Distance covered in zone 1[m]	F=34.090; p<0.001	p=0.011	NS	NS
Distance covered in zone 2[m]	F=14.725; p<0.001	p<0.001	p=0.048	p=0.033
Distance covered in zone 3[m]	F=35.956; p<0.001	p<0.001	p<0.001	p=0.023
Distance covered in zone 4[m]	F=33.559; p<0.001	p<0.001	p<0.001	NS
Distance covered in zone 5[m]	F=27.451; p<0.001	p<0.001	p<0.001	NS

NS – non-significant

It was also found that the response of the circulatory system to the applied exercise load was different in the three exercise phases. The exercise performance duration at five submaximal HR zones was different in the WU, FH and SH phases (Table 6).

Table 6 **Statistical analysis of the time spent by a soccer player in different HR zones**

Parameters	Analysis of variance	Post hoc analysis		
		1vs2	***1vs3***	***2vs3***
HR duration in zone I [s]	F=29.488; p<0.001	p<0.001	p=0.005	NS
HR duration in zone II [s]	F=4.707; p=0.040	p=0.002	p=0.008	NS
HR duration in zone III [s]	F=6.584; p=0.006	p=0.005	NS	NS
HR duration in zone IV [s]	F=6.098; p=0.009	p=0.013	p=0.034	NS
HR duration in zone V [s]	F=11.472; p=0.003	p<0.001	p=0.012	p<0.001

NS – non-significant

Post hoc analysis showed that in HR zones of a more moderate level, i.e. 50-59 % HRmax and 60-69 % HRmax, more time was spent during the WU than in the FH and the SH, and in the zone of 70-79 % HRmax more time was spent in the WU than in the FH (p=0.005). However, in the ranges of 80-89 % HRmax and 90-100 % HRmax, the time spent at such high HR values was significantly shorter in the WU period than during the FH and the SH. It was also shown that the absolute values of HRmin (F=11.488, p<0.001) and HRmean (F=14.191, p=0.002) were significantly different between the exercise phases (Table 7). Post hoc analysis showed that significantly higher HRmin values were achieved in the FH than in the WU (p<0.001) and the SH (p=0.023), while HRmean values were significantly lower in the WU than during the FH and SH (p<0.001). Interphase differences of relative HR were similar to absolute values of this physiological variable.

Table 7 **Statistical analysis of heart rate**

Parameters	**Analysis of variance**	**Post hoc analysis**		
		1vs2	***1vs3***	***2vs3***
HRmin [bpm]	F=11.488; p<0.001	p<0.001	NS	p=0.023
HRmean [bpm]	F=14.191; p=0.002	p<0.001	p<0.001	NS
HRmax [bpm]	F=1.187; p=0.349	-	-	-
HRmin [%]	F=11.453; p<0.001	p<0.001	NS	p=0.033
HRmean [%]	F=14.333; p=0.002	p<0.001	p<0.001	NS
HRmax [%]	F=1.880; p=0.208	-	-	-

NS – non-significant

The obtained results show that the load on the players' body during the WU was lower than during FH and SH, which was comparable in both parts of the match.

Discussion

The soccer players in this study covered the longest distance during the FH and the shortest distance during the WU, there being thus also a difference between the distances covered during the FH and the SH. Such a variation between the FH and the SH is consistent with the literature, pointing to the fact that the total distance covered in the SH of a soccer match is less than in the FH at the highest and medium levels of the sport (Barros et al., 2007; Mohr et al., 2008). This tendency has been demonstrated in the current study by players, who, according to objective criteria, would be considered to be of an average national professional level. It is unfortunate that the available literature does not provide evidence regarding the physical loads that occur during the WU. As a result, no previous comparison of the WU with both parts of the subsequent match has been made. The present work thus presents something new. From the analysis in the current study of the loads sustained during the three phases of exercise, it is clear that greater attention should be paid to the constituent elements of the WU. The warm-up phase is important because while on the one hand it should be intense enough to make the body flexible and prepare its individual systems for increased physical loads, on the other hand it should not be so intense as to cause premature fatigue, and thus possibly have an adverse effect on the overall result of the match.

It was also noted in the current study that the maximum running speed and the number of sprints performed during each of the three phases were similar. These intense forms of running loads experienced at the highest speed constitute only 10-20 % of the overall effort expended during the match, which for 80-90 % of the time is played at low and moderate running speeds (Bloomfield et al., 2007). Data provided by Barros et al. (2007) and Mohr et al. (2008) indicate that as a result of progressive fatigue experienced in the SH, soccer players make in that part of the match a smaller number of sprints and high intensity efforts than in the FH. There are, however, studies showing that high-intensity runs are maintained equally throughout the duration of a match by both young (Da Silva et al. 2007; Castagna et al. 2003) and adult soccer players (Barros et al. 2007). It has been considered that it is the maximal speed of a run, the distance covered, the number of sprints, and the high average speed of runs performed during a match that are the main factors determining the state of physical preparation of a soccer player (Gregson et al., 2010; Ingebrigtsen et al., 2015). If that is the case, then it is reasonable to conclude that the actual distances run in different ranges (zones) of running speed also constitute an important factor. In the present study there were significant differences in this respect; the longest distances in the WU period were covered at a speed of 3.00-6.99 km/h, and in both parts of the match itself the longest distances were covered at speeds of 7.00-10.99 km/h and 11.00-14.99 km/h. The current study also confirmed that the running distance covered during the FH was greater than during the SH, and this result was observed in the two speed zones, 7.00-10.99 km/h ($p=0.033$) and 11.00-14.99 km/h ($p=0.023$). A global analysis of the running loads sustained during the three exercise phases of the current study thus showed that both the achieved distances (in different speed zones) and the achieved speeds themselves consistently differentiate the WU from the FH and SH, and also the FH from the SH.

It is interesting to see whether the applied running loads are closely mapped by HR changes. It seems that such a mapping does occur, because both HRmean and HR achieved in the five separate zones (50-100 % HRmax), significantly differentiate the WU, FH and SH phases. However, changes in HR are not as sensitive an indicator of body workload as the distance covered, because some of the results do not show differences between the FH and the SH or significant differences in running loads.

It has previously been shown that HRmean achieved during a 90-minute match can range from 155 to 172 bpm (Eniseler, 2005), which corresponds to 85 % HRmax (Helgerud et al., 2001). Such a relatively high workload on the body corresponds to the HR observed at the anaerobic threshold (Stølen et al., 2005). Loads during the WU in the present study were lower than the anaerobic threshold: HRmean was at the level of 68.46±5.35 % HRmax, with an average speed of movement equal to 3.52 km/h. The low, under anaerobic threshold, intensity (i.e. not leading to a higher level of physical performance) of the WU is also supported by the fact that during the match itself the players stayed for the longest periods of time in the low and medium HR zones of 60-69 % HRmax and 70-79 % HRmax and in the low speed range of 3.00-6.99 km/h. Interpretation of the results obtained in the WU should also take into account that the purpose of the WU is not to train the body, but only to prepare it for more intense efforts

(Sander et al., 2013). In the current study, in the FH the players achieved HRmean= 85.00±7.71 % HRmax, and stayed for the longest periods of time in the cardiovascular load ranges of 80-89 % HRmax and 90-100 % HRmax and in the medium-intensity running speed zones of 7.00-10.99 km/h and 11.00-14.99 km/h. During the SH, HRmean was achieved at 81.18±6.66 % HRmax, and the players spent the longest periods of time in the cardiovascular load range of 80-89 % HRmax and the medium-intensity running speed zones of 7.00-10.99 km/h and 11.00-14.99 km/h. The values of HR appearing in the FH and SH suggest that the body workload in these periods can be high enough to reach the anaerobic threshold, which would lead to the further development of physical performance. However, the running speeds recorded in both parts of the match, but particularly in those in which the players covered the greatest distances, did not always indicate that anaerobic threshold loads had been achieved, especially as the average running speed during the FH was 6.93±1.37km/h and during the SH was 6.28±1.23 km/h, with maximal values of these variables equal to 27.80±4.23 km/h and 29.10±4.26 km/h, respectively. Probably only sprints and running at speeds above 19 km/h should be counted as above-anaerobic threshold workloads. However, during the match and WU there were few such instances (in the current study they lasted no more than 5 minutes), although such episodes can determine to a large extent the outcome of a game (Gregson et al., 2010).

In summary, the analysis of workloads during the WU, FH and SH can be performed by tracking HR changes, as well as by recording the length and speed of runs. Tracking such changes in the cardiovascular system enables the distinguishing of differences between lower and higher workloads in relation to exercise intensity observed at the anaerobic threshold.

Conclusion

1. The total length of the distance run, the average speed of run, and the distances covered at different speeds are good indicators for differentiating physical activity during the warm-up and both halves of a soccer match involving young soccer players.
2. The body's response to differential running loads during the warm-up and both halves of the match as expressed by submaximal heart rate in specific zones changes, minimal and average heart rate, was different during warm-up and both parts of the match, and adequate to the running load.
3. Warming-up constituted a smaller workload than did both halves of the match itself. Sporadic workload demands on the body were the biggest during the first half of the match and in some part exceeded the workloads occurring at the anaerobic threshold.

4. There is an urgent need to extend the results obtained in the current studies to the biochemical and physiological reactions of the organism and to link them to the indicators of the effectiveness of the game.

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