

How Much Does the Warm-Up Contribute to the Soccer Match-Day Load?

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Warm Up | Match demands | Soccer | NCAA

Headline

During competitive soccer matches, collegiate females cover approximately 10km of total distance (5, 6, 9, 10). We and others have found that they exercise at about 80% of maximal heart rate and expend nearly 50 kJ of energy per kg body mass (4, 10). Prior to each match, teams conduct a pre-match warm up that includes both physical activities and technical skills. Unfortunately, data concerning the physiological demands of the warm-up are scarce. This is unfortunate since this period of activity likely contributes to the overall workload during the session.

Aim. The purpose of this study was to address four questions: 1) How do the physical demands of the warm-up compare to match loads? 2) Does the warm-up differ between starting and non-starting (reserve) players? 3) Do the velocity and intensity of the warm-up influence performance at the start of the match? And 4) Does the warm-up influence performance at the end of the match?

Methods

Subjects were 21 members of an NCAA Division I women's collegiate soccer team (63.0±6.4 kg, 167.6±5.6 cm, 19.3±1.1 y, mean±SD). All players wore a GPS-embedded accelerometer (GPSports) and heart rate (HR) monitor. Data from these devices were downloaded and analyzed using the manufacturer's software (Team AMS). All methods were approved by the Virginia Tech Institutional Review Board and informed consent was obtained prior to data collection.

Players were divided into several groups. We first compared the warm-up and match loads in full time (FullTime) players. This groups included players who started the match and played the entire 90 min (9 players, 78 player x matches). Next, we compared warm-up loads between starts and reserves. For this comparison, players who started the match and participated with the starting group during the warmup (see below) were classified as Starters (15 players, 197 player · matches). Since NCAA rules allow players to re-enter the match after being subbed out, many starting players played less than 90 min. Thus, not all Starters are included in the FullTime group. Players who did not start the match were classified as Reserves (13 players, 139 player · matches). This group included players who entered the match after the 25 min mark as well as players who did not play. A total of 22 matches were analyzed. A typical example of the warm-up routine is shown in Table 1. The nature of the warm-up for each varied slightly from match to match. However, a consistent pattern was followed. All players began with 8-10 min of active stretching, jogging and change of direction movements. Next, players were divided into Starters and Reserves. The two groups played small sided games for 10-15 min. Players then returned to a single group and took part in crossing and shooting drills with keepers for 8-10 min. After these activities, all players returned to the bench area to hydrate and change into match jerseys. Several short sprints were then

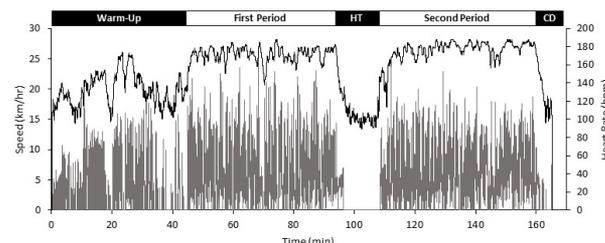


Fig. 1. Raw typical HR and speed data for FT player during the match. HT = half-time, CD = cool-down.

performed before the national anthem was played and player introductions were made. Thereafter, the match began. A typical example of the warm-up routine is shown in Table 1. For this study, the warm-up period was defined as beginning with the active stretching period and ending with kick-off.

For all variables, means and standard deviations (SD) were computed. Group comparisons were made using effect sizes (Cohen's d). Relationships between variables were computed using Person-Product Moment correlations.

Results

Sample speed and HR data for the warm-up and match are shown in Figure 1. Note that during half-time, the GPS signal was lost as the player entered their locker room. The duration of the warm-up was 38.8 ± 5.42 min (mean±SD) or 43% of the match duration. A typical pre-match warm-up lasts between

		Warm-Up					
		TotDist	Sprints	SprDist	EE	AvgHR	BL
0-15 min	TotDist	0.4022 ^M	0.5665 ^L	0.4300 ^M	0.4173 ^M	0.0915	0.1205 ^S
	Sprints	0.5310 ^L	0.0347	0.6196 ^L	0.5658 ^L	0.2102 ^S	0.0207
	SprDist	0.5322 ^L	0.6283 ^L	0.6252 ^L	0.5760 ^L	0.2354 ^S	0.0443
	EE	0.2963 ^S	0.3808 ^M	0.3509 ^M	0.3248 ^M	0.1496 ^S	0.0687
	AvgHR	-0.0102	0.1409 ^S	-0.0001	0.1496 ^S	0.5689 ^L	0.0210
	BL	-0.0459	-0.0874	-0.1006 ^S	-0.0453	-0.0394	0.1040 ^S

Effect size designation are S - small (0.1-0.3), M - medium (0.3-0.5, shown in blue) and L - large (>0.5, shown in red).

Fig. 2. Correlation coefficients between warm up and the 0-15 min match segment values for the Starters only.

		Warm-Up					
		TotDist	Sprints	SprDist	EE	AvgHR	BL
75-90 min	TotDist	0.2541 ^S	0.3274 ^M	0.3526 ^M	0.2901 ^S	0.1144 ^S	0.1570 ^S
	Sprints	0.2075 ^S	0.4710 ^M	0.4708 ^M	0.1663 ^S	0.0472	0.1340 ^S
	SprDist	0.1200 ^S	0.4400 ^M	0.4693 ^M	0.0983	0.0325	0.0574
	EE	0.2512 ^S	0.3952 ^M	0.4059 ^M	0.2784 ^S	0.0813	0.1716 ^S
	AvgHR	-0.1369 ^S	0.0669	0.0371	-0.2190 ^S	0.0432	0.0614
	BL	-0.0891	-0.0805	-0.0566	-0.0915	-0.0656	-0.0129

Effect size designation are trivial (<0.1), S - small (0.1-0.3), M - medium (0.3-0.5, shown in blue) and L - large (>0.5)

Fig. 3. Correlation coefficients between warm up and the 75-90 min match segment values for the FullTime players only.

Table 1. A typical example of the duration and activities included in the pre-match warm-up. For this match, kick-off was scheduled for 19:05.

Time	Duration	Activity
18:22-18:32	10:00	Dynamic warm-up. Active stretching, jogging, change of direction movements. All players participated as one group.
18:32-18:46	14:00	Small-sided games. All players participated but were divided into two groups, Starters and Reserves.
18:46-18:55	9:00	Technical and tactical work. Shooting, crossing and finishing drills with goal keepers. All players, one group.
18:55-19:00	5:00	Return to bench area, hydration, change into match jerseys. Followed by several short (5m) sprints. All players, one group
19:00-19:05	5:00	National anthem and player introductions. All players, one group.
19:05		Start of match. Starters only.

Table 2. Comparison of the Warm-up and Match for FullTime players only (players who started and played 90 min).

Variable	Warm Up		Match		% Match Activity	
	Mean	SD	Mean	SD	Mean	SD
TotDist (m)	2033.70	233.72	9476.85	1017.96	21.56	2.22
Sprints (n)	24.69	7.69	71.40	24.61	36.70	11.75
SprDist (m)	216.24	79.27	880.28	350.62	26.71	9.87
EE (kJ/kg)	10.54	1.30	47.49	5.41	22.29	2.28
AvgHR (bpm)	146.22	9.73	170.12	15.74	87.48	18.83
BL (au)	29.23	26.84	117.38	34.00	23.55	9.51

TotDist = total distance covered, Sprints=total number of sprints executed, SprDist=distance covered during sprinting, EE=energy expenditure, AvgHR=average heart rate, BL=body load.

Table 3. Comparison of the Warm-up and Match for FullTime players only (players who started and played 90 min).

Variable	Starters		Reserves		ES ¹	% Diff
	Mean	SD	Mean	SD		
TotDist (m)	2140.49	247.03	1773.63	286.60	1.3712 ^{VL}	18.7
Sprints (n)	29.15	9.42	25.24	7.62	0.4564 ^S	14.4
SprDist (m)	265.47	95.93	229.67	67.08	0.4325 ^S	14.5
EE (kJ/kg)	10.85	1.67	9.68	1.41	0.7562 ^M	11.4
AvgHR (bpm)	146.79	11.36	142.29	13.82	3.1100 ^H	13.8
BL (au)	27.59	7.38	27.53	9.28	0.0072 ^T	0.22

¹Effect size (ES) designations are T- Trivial (<0.2), S – small (0.2-0.5), M – medium (0.5-0.8), L – large (0.8-1.2), VL – very large (1.2-2.0) and H – huge (>2.0).

25 and 40 min (11). In a detailed survey of professional team practitioners, Towson et al. (8) report that active warm-ups prior to a soccer match last 15-45 min (mean = 31 min) with an additional 12 minutes of “down-time” prior to kick-off. The present data suggest that college females undergo a warm-up of similar duration to those of professional males.

Warm-up vs Match. Our first objective was to compare warm-up and match loads. For this analysis only FullTime players, those who started and played 90 min, were included (Table 2). Warm-up HR was about 87% of match and was $73.2 \pm 5.7\%$ of maximal HR. The physical demands of the warm-up ranged from 22-37% of match loads. The warm up added an additional 2 km of TotDist and 200m of SprDist to the match-day load. The TotDist value is similar to that reported by Gentles et al. (2) for an NCAA Division II team. Further, the warm-up required an additional 10-11 kJ/kg of energy expenditure or $\approx 22\%$ of that expended during the match. For our players, this amounts to average of 150 kcal.

Starters vs Reserves. Our second objective was to compare the warm-up loads between Starters and Reserves (Table 3). This was done as these groups were used during the small-sided games portion of the warm-up which may have resulted in different volumes and intensities of activity. Starters consistently experienced greater volume (higher TotDist and EE) and in-

tensity (Sprints, SprDist and AvgHR). While the differences ranged from 11 to 19%, the effect sizes were very large. The exception was BL where the effect size between groups was trivial. It is not clear why the discrepancies between groups exist. In general, activities between groups were identical. It may be that during the small sided games, Starters covered more distance and at higher intensities. Further, the pre-match mental stress associated with starting may have elicited higher work rates in this group. Despite the differences between groups, it is important to note that the volume and intensity of the Reserves during the warm-up. Previous work with this team of players indicates that the Reserves pre-match warm up is slightly less in volume but greater in intensity compared to a typical post-match recovery day for FullTime players.

Warm-up vs Start of Match. To determine if the intensity and volume of the warm-up influenced efforts during the initial minutes of the match, we compared warm-up data with values obtained during the first 15 min of the match (0-15 min) (Figure 2). The strongest relationships were noted between the running and energy expenditure variables. In general, the greater the TotDist, Sprints, SprDist and EE experienced during the warm-up, the greater these load metrics were during the match. Higher warm-up HR was also associated with higher 0-15min HR. It is not clear if these are cause-and-effect relationships suggesting greater warm-up loads translate into

greater match performance. Further, it should be noted the values observed during the warm-up generally accounted for a small percentage of the variance in the 0-15 min values.

Warm-up vs End of Match. Gregson et al (3) suggest that a prolonged warm-up may deplete energy stores which could lead to fatigue. Thus, we also determined if the volume and intensity of the warm-up affected performance near the end of the match (75-90 min). Figure 3 shows the correlation coefficients for the warm-up and this match period. As can be seen, there were several medium to small effect sizes suggesting greater warm-up load reduced performance during the 75-90 min interval. However, the magnitudes of the r-values indicate that only a small amount of the variation in late-match performance could be attributed to the warm-up. Thus, it is unclear to what extent to warm-up may or may not contribute to fatigue at the end of a match.

Discussion

The key finding of this study is the pre-match warm-up can add an additional 20-30% to the match physical demands. Compared to Starters, Reserve players, including players who do not participate in the match perform less work during warm-up. Given this, it is clear that the warm-up should be included when calculating total load experienced during match day. Recently, training load, specifically the ratio between short- and long-term loads (e.g. acute:chronic ratio), has been recommended as a marker for managing injury risk (1). Failure to include warm-up activities in this calculation could lead to under-estimation of actual loads as well as potential injury risk. This could be particularly important for players who do not participate in the match but engage in the warm-up. Pustina et al. (7) note that including the duration of the warm-up in the session rating of perceived exertion (RPE) calculation (duration x RPE score). They attribute this to the player's perception of the warm up as much less strenuous than the match. This perception may be accurate. For example, the 39 min warm up equates to 43% of match duration but only $\approx 22\%$ of TotDist. Also, Starters and Reserves appear to experience different warm-up demands. Given this, it is possible that use of RPE to quantify session load may require separate individual ratings for the warm-up and match. Lastly, it does not appear that a warm up of the duration and intensity within the range used here has marked effects on physical performance early or late in the match. Unfortunately, previous work concerning the warm-up and subsequent performance lacks ecological validity regarding the types of activities, volume and intensity that lead to improved soccer match performance (4). Thus, additional work is needed to determine the optimal warm-up to maximize physical, technical and tactical performances during the match.

Practical Applications

- The activities of a pre-match warm-up add an additional 25-30% to the load experienced during the match. Also Starters experienced 11-18% greater volume and $\approx 14\%$ greater intensity than Reserve players.
- The additional load experienced during the warm-up should be considered and taken into account when estimating the load for the entire session. It should also be considered into calculations of metrics designed to aid in the management of loads across a season.
- The additional energy expenditure during the warm-up should be combined with match energy expenditure when developing post-match nutritional recovery strategies.

Limitations

- Our results are limited to a single collegiate team monitored during a single season. It is possible that our data are not reflective of the all collegiate teams.
- While the number of matches (n=22) and player · matches in our study was large (n=78-137), the number of players within the various groups was somewhat small (n=9-15).
- Due to player substitution routines, most of the players in the FullTime group played defensive roles. Attacking players generally played less than 90 min.
- We did not account for the match schedule. As women's collegiate teams often play two matches per week, it is possible that the coaching staff altered the warm up during some matches to account for such a congested competitive schedule.

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References

1. Gabbett TJ. The training—*injury prevention paradox*: should athletes be training smarter and harder? *Br J Sports Med.* 2016; 50: 273–280.
2. Gentles JA, Coniglio CL, Besemer MM, Morgan JM, Mahnken MT. The demands of a women's college soccer season. *Sports.* 2018; 6: 16.
3. Gregson W, Batterham A, Durst B, Cable N. The influence of pre-warming on the physiological responses to prolonged intermittent exercise. *J Sport Sci.* 2005; 23: 455-464.
4. Hammami A, Zois J, Slimani M, Russell M, Bouhleb E. The efficacy, and characteristics of warm-up and re-warm-up practices in soccer players: a systematic review. *J Sports Med Phys Fitness.* 2018; 58: 135-149.
5. Jaskowak DJ, Williams JH, Tegarden DP. Use of a GPS-embedded accelerometer to evaluate the complexity of the running gait. Part 2: Effects of fatiguing activity. *Sport Perf Sci Reports.* 2018; in review.
6. McCormack WP, Hoffman JR, Pruna GJ, Scanlon TC, Bohner JD, Townsend JR, Jajtner AR, Stout JR, Fragala MS, Fukuda DH. Reduced high-intensity-running rate in college women's soccer when games are separated by 42 hours. *Int J Sports Physiol Perf.* 2015; 10: 436-439.
7. Pustina AA, Sato, K, Liu C, Kavanaugh AA, Sams ML, Liu J, Uptmore KD, Stone MH. Establishing a duration standard for the calculation of session rating of perceived exertion in NCAA division I soccer. *J Trainology.* 2017; 6: 26-30.
8. Towlson C, Midgley AW, Lovell R. Warm-up strategies of professional players: practitioners' perspectives. *J Sport Sci.* 2013; 31: 1393-1401.
9. Vescovi JD, Favero TG. Motion characteristics of women's college soccer matches: Female Athletes in Motion (FAiM) study. *Int J Sports Physiol Perform.* 2014; 9: 405-414.
10. Williams JH, Hoffman S, Jaskowak DJ, Tegarden D. Physical demands and physiological responses of extra time matches in collegiate women's soccer. *Sci Med Football,* in review.
11. Zios J, Bishop DJ, Ball K, Aughey RJ. High-intensity warm-ups elicit superior performance to a current soccer warm-up routine. *J Sci Med Sport.* 2011; 14: 522-528.

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