Journal of Physical Fitness, Medicine & Treatment in Sports

Juniper PUBLISHERS key to the Researchers

Review Article
Volume 10 Issue 1 - March 2023
DOI: 10.19080/JPFMTS.2023.10.555779

J Phy Fit Treatment & Sports
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The Effects of Circadian Rhythms on Physical Performance in Elite-Level Soccer

Adam Owen[1,2]*, Mehdi Rouissi[3], Chtara Moktar[3], Matthew Newton[4], Osman Ates[5], Ekin Karlik[5], Anthony Weldon[6] and Colin Clancy[7]

[1]*KKS Lech Poznan, Ekstraclasa, Poznan, Poland*

[2]*Inter-university Laboratory of Human Movement Biology, University Claude Bernard Lyon 1, University of Lyon, Lyon, France*

[3]*Tunisian Research Laboratory "Sport Performance Optimization", National Centre of Medicine and Science in Sports, Tunis, Tunisia*

[4]*Cardiff City Football Club, Cardiff, Wales, UK*

[5]*Istanbul Üniversitesi Cerrahpaşa, Sport Science Faculty, İstanbul, Turkey*

[6]*Technological and Higher Education Institute of Hong Kong, Hong Kong*

[7]*Hibernian Football Club, Edinburgh, Scotland, UK*

Submission: January 20, 2023; **Published:** March 01, 2023

***Corresponding author:** Adam Owen, KKS Lech Poznan, Ekstraclasa, Poznan, Poland

Abstract

The purpose of this study was to examine the influence of circadian rhythm on physical performance during a match-preparation training sessions (MD-1) in elite soccer players. Over a 28-week period, a standardised MD-1 training session was alternated between morning and afternoon start times. Physical performance (Total Distance, High Speed Running, Dynamic Stress Load, Accelerations, Decelerations and Explosive Distance) was assessed during each session to examine the effect of time of day on performance. There was evidence of enhanced physical performance during morning training sessions that reached statistical (P<0.05) and practical (33.8% {greater in morning}) significance. Higher locomotor outputs during morning training sessions may be driven by the influence of circadian rhythms optimising physiological, hormonal, and psychological capabilities. Coaches and practitioners should consider the scheduling of training sessions to maximise physical performance.

Keywords: Circadian Rhythms; Dynamic Stress; Chronobiological Factors; Athletes; Football Club

Abbreviations: TD: Total Distance; HSR: High Speed Running; DSL: Dynamic Stress Load; ED: Explosive Distance; SD: Standard Deviations; ES: Effect Size; SWC: Smallest Worthwhile Change

Introduction

Elite-level soccer players are placed under regular physiological and cognitive strain during training and match-play. To gain a better understanding of the strain imposed, contemporary research [1-3] has examined the impact of several physiological, biochemical, and cognitive factors on physical performance, fatigue, and recovery, of elite-level soccer players. Although meaningful research [1-3] has explored these relationships, our understanding of the impact of chronobiological factors, such as circadian rhythms, on physical performance in elite-level soccer is limited in comparison.

Reilly et al [4] defined circadian rhythmicity as "24-hour variations in both endogenous and exogenous factors", highlighting diurnal biochemical and physiological variability is a result of several external and internal factors. Dos Santos et al [5] further explained that the endogenous factors impacting diurnal variability include "changes in body temperature, cardiac function, sleep-wake cycle and the release of hormones: melatonin, cortisol, adrenaline". The exogenous impacts of circadian rhythms include external natural light sources, the time food is consumed, and exterior temperature [4]. Research suggests these exogenous and endogenous components can significantly impact physical and mental performance over a day [6].

It has been observed that soccer players' physical performance can significantly improve throughout a day, with the evening period producing an improved performance in standardised running and fitness tests [4]. These ameliorations in physical performance towards the end of a day may be attributable to a progressive and natural increase in core body temperature [4,5]. Conversely, Reilly et al. [4] study found soccer players performed significantly better in challenging cognitive tasks in the morning compared to the evening. With a possible explanation being that in the morning players had less cognitive and mental fatigue, in comparison to the evening [4]. However, it has been suggested by Drust et al. [6], that players develop a "peak window" of 24-hours, whereby performance is optimised. Reason being, athletes typically wake up, train and sleep, at similar times daily, which may predispose players to perform significantly worse when training or competing outside their "peak window" [6].

The impact of chronotype has been more recently explored on the physical performance outcomes in elite-level sport, which considers important factors such as sleep quality and training/match-play time schedules Bonato et al. [7], suggests categorising individuals into three chronotypes, "Morning-type (M-type), Evening-type (E-types), and Neither-type (N-type)". In general, M-types perform better earlier in the day, as they wake up and go to bed earlier. In contrast, E-types typically perform better later in the day, as the times they wake up and go to bed are later [7]. Research has shown that there are clear differences in performance outcomes between M-type and E-type athletes, depending on the time of day they are tested [8,7]. For example, Bonato et al. [8] found that when high-intensity interval training was performed earlier in the day, E-type athletes produced greater levels of salivary cortisol than M-type athletes thereby indicating these athletes experienced a greater level of stress, than M-type athletes. Moreover, [7] found that M-type players fatigued earlier than players with the E-type chronotype during evening matches.

This would suggest that chronotypes play a significant role in the physical performance and fatigue of soccer players. Consequently, practitioners should consider a player's chronotype, so that, depending on the time-of-day training or match-play is prescribed, practitioners can subsequently provide pertinent sleep hygiene methods to the relevant athletes, to help increase their preparedness to perform [8,7]. It has been suggested that diurnal variability in exogenous and endogenous factors can have a significant impact on performance markers in elite-level sport [4-6]. Consequently, the effects of circadian rhythmicity can provide practitioners with an insight into prescribing training for optimal performance in both training and match-play. Historically, competitive soccer match-play occurred on similar days and at similar times, however in more recent times, match schedules are increasingly diversifying to cater for the significant global television demands, with matches occurring at atypical hours of the day [8].

As such, elite-soccer match times can range from mid-morning to late evening, with players expected to perform optimally at any time [4]. While the scheduling of competitive matches differs significantly across a season, training typically occurs in the morning [9]. Interestingly, Reilly et al. [4] found that players performed at their best in both physical and football-specific tasks, between the hours of 16:00 and 20:00. Dos Santos et al. [5] found that players covered a greater distance at average-intensities (11 - 18 km/h) in games taking place at 21:00, compared to 16:00.

Therefore, it could be argued based on the available evidence that to coincide with peak core body temperatures and higher physical performance outputs, training should be prescribed during these periods, to greater optimise training performance. Nevertheless, more research is needed in this area to uncover the true benefits of optimising training schedules for physical performance in elite-level soccer. As a result of the lack of research in this area, our study aimed to investigate the effects of circadian performance in elite level players.

Participants

Thirty senior elite-level European professional soccer players competing in the first division of their competitive league, participated in this study. Thirteen players at the time of study were members of their national team (full or youth internationals). The players' age, height, body mass, sum of eight skinfold sites, and maximal aerobic capacity were 25.3 ± 5.3 years old, 183.4 ± 5.1cm, 79.4 ± 7.7kg, 57.4 ± 9.5mm, and 52.3 ± 3.6 ml · kg-1 · min-1 respectively. After a detailed explanation of the investigation, all participants provided informed consent for their data to be included in the study. The players were informed that they were able to withdraw their data and information from the study at any time. Before the study commenced, it received full approval from the Sports Science and Medical Department at the participating Football Club. The study adhered to the principles outlined within the Declaration of Helsinki.

Procedures

Participants training data was collected across 28-weeks to assess the effects of training time on physical performance. Over the study period, data from a standardised training session held the day before a game, referred to in this study as "MatchDay-1" or "MD-1" was selected for analysis. Training session time was randomly alternated between two categories: "Morning" and "Afternoon". The average start time of the Morning training sessions was 11:37:30 ± 00:21 and the average duration of these sessions was 47 ± 14 mins. The average start time of Afternoon training sessions was 16:13:20 ± 00:50 and the average duration of these sessions was 51 ± 7 mins.

To track and monitor participant's movement demands in training, a non-differential 10-Hz GPS device was used (STAT Sports, 10-Hz, Viper Pod, Northern Ireland). This system has been validated and utilized in previous studies [10,11] to effectively quantify the movement demands of players in elite-level team sports [12,13]. Each participant was assigned a unique GPS unit, which was held between the scapulae in a tightly fitted vest. Participants always used the same GPS units and wore the same GPS vests to reduce inter-unit error [14].

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GPS devices were activated in an open outdoor space at least fifteen minutes before the beginning of any training session to enable successful acquisition of satellite signals, and in turn, to accurately record data [14].

Once training sessions were recorded, data was subsequently downloaded and analysed using the STAT Sports Viper software (STAT Sports, Viper Pod, Northern Ireland). For this study, the GPS metrics selected were as follows: Total Distance (TD), High Speed Running (HSR) (distance covered at a speed > 19.8km/h), High Speed Running per minute (HSR/min), Dynamic Stress Load (DSL), Accelerations Count (number > 3.3m·s-2), Decelerations Count (number > 3.3m·s-2) and Explosive Distance (ED) (distance covered above 25.5W/kg and below 19.8km/h). The DSL refers to the total weighted impacts based on accelerometer values greater than 2g (STAT Sports, Northern Ireland). The GPS and accelerometer-derived metrics listed above are representative of common measures utilized to monitor training loads in elite-level soccer players [9].

Statistical Analyses

Means ± standard deviations (SD) were used to describe dependent variables. Before using parametric tests, the assumption of normality was verified using the Kolmogorov-Smirnov test. A paired sample t-test was used to determine significant differences between the scores recorded during the two trials (morning vs. afternoon) for all variables. The Effect size (ES) was calculated for all paired comparisons and interpreted as small < 0.50, moderate = 0.50-0.80, and large > 0.80. In addition to the comparison analyses, the smallest worthwhile change (SWC), and the likelihood of clinical meaningfulness were calculated for all dependant variables. The threshold of a clinical meaningful effect was set at 75% The quantitative chances of beneficial effects were assessed qualitatively as follows: <1% almost certainly not, 1-<5% very unlikely, 5-<25% unlikely, 25-<75% possible, 75-<95% likely, 95-<99 very likely, and ≥99% almost certain. Statistical analyses were performed using SPSS software statistical package (SPSS Inc., Chicago, IL, version. 26.0), and statistical significance was set at P < 0.05.

Results

Analysis with repeated measures

Means and standard deviations of dependent variables are reported in (Table 1) The Paired sample t-test showed significant differences between the scores recorded during the two sessions for TD, accelerations count, decelerations count, and ED (P < 0.01; ES=moderate to large), (Figure 1). The scores performed in the morning are much better than those performed in the afternoon. For the HSR, HSR/min, and DSL, no significant effect for time (P > 0.05) was observed.

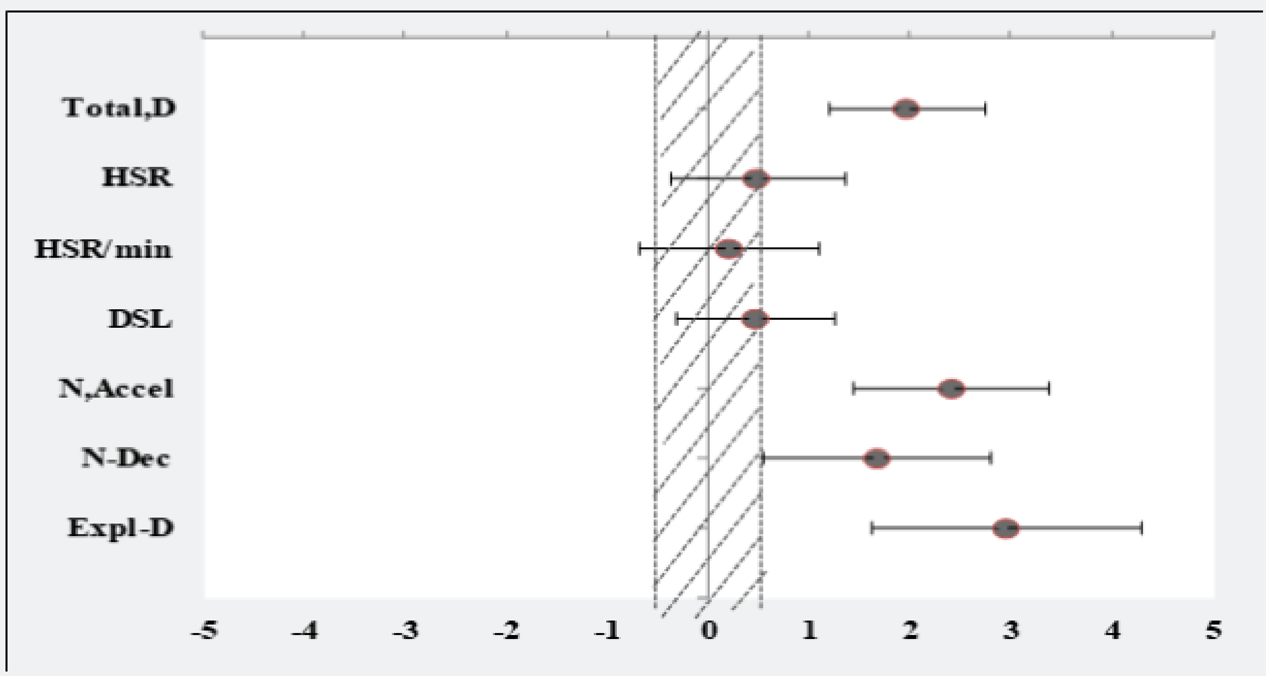

Figure 1: Points represent the effect size while error bars represent 95% confidence limits on the mean effect.

Table 1: Comparison between scores performances.

Variable	Morning (11:37)	Afternoon (16:14)	P-value
TD	2748.65±124.80	2398.23±178.97	0.001
HSR	26.31±11.93	20.15±13.04	0.248

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HSR/min	0.44±0.21	0.39±0.27	0.625
DSL	48.41±10.87	43.26±11.12	0.212
Acceleration Count	21.20±4.78	14.04±2.97	0.001
Deceleration Count	20.38±5.86	14.45±3.55	0.009
ED	238.71±44.74	164.37±25.22	0.001

TD = Total Distance

HSR = High Speed Running

DL = Dynamic Stress Load

ED = Explosive Distance

Magnitude-based Inferences

For the TD, accelerations count, decelerations count, ED, HSR, and DSL, session morning protocol elicited changes that had >75% likelihood of exceeding the SWC (76.76 to 99.97%). In contrast, the HSR/min was unaffected by any of the conditions (morning vs. afternoon) with no protocol eliciting a 75% likelihood of exceeding the SWC (Table 2).

Table 2: The precision of the predicted increase from afternoon session for all tests.

Variable	Mean Difference	95% Confidence Limits		Cohen's d	Likelihood of exceeding smallest worthwhile change (%)			No. of subjects whose performance is better than the control session
		Lower	Upper		Higher	Trivial	Detrimental	
TD	350.42±19	212.87	487.98	1.96	99.97	0.02	0.01	9
HSR	6.16±15.76	-5.12	17.43	0.47	75.26	19.11	5.63	6
HSR/min	0.05±0.34	-0.18	0.3	0.2	49.7	33.6	16.7	6
DSL	5.15±12.13	-3.52	13.83	0.46	76.76	18.9	4.33	8
Accelerations count	7.164.02	4.28	10.03	2.41	99.97	0.02	0.01	10
Decelerations count	5.93±5.64	1.89	9.96	1.67	99.15	0.61	0.24	9
ED	74.34±47.05	48.68	108	2.95	99.94	0.04	0.02	10

TD = Total Distance

HSR = High Speed Running

DL = Dynamic Stress Load

ED = Explosive Distance

Individual Responses

Figure 1 shows the results as a percentage of the baseline performance, with each baseline performance considered to be 100% of the individual's maximal performance (i.e., a sprint time of less than 100% represents an improved performance). Illustrates the individual changes of each subject for each test (where no bar appears for a subject, this represents a 0% change). The graph illustrates that the range of responses by everyone varied between subjects and tests. There was a great consistency between the results, with patterns emerging on the responders and non-responders to the sessions protocols. Most subjects responded positively to the morning session. (Table 1, 2), (Figure 1).

Discussion

Our most important findings were that the TD (P = 0.001), acceleration count (P = 0.001), deceleration count (P = 0.009) and ED (P = 0.009) in morning training were statistically higher than when compared to same sessions performed during evening training. Furthermore, HSR (P = 0.248), HSR/min (P = 0.625), DSL (P = 0.212) were in morning higher than when compared to evening training. However, our results in these parameters are not statistically different.

Reilly et al emphasized that football-specific abilities and performance are maximum between 16.00-20.00 [4]. In contrast, our data supports the notion that aspects of physical performance

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during training sessions are greater when performed in the morning. It may be speculated that these differences in results are due to the difference in our performance criteria. In a review study where the results of nine randomized controlled trials were discussed, it was emphasized that evening training was higher in football-specific abilities than morning training [15]. However, in this review the parameters included were strength, agility, and flexibility. In our study, parameters analysed such as TD, accelerations count, decelerations count and ED which have not been previously studied in the literature. Although high intensity locomotor outputs such as accelerations and decelerations are driven by strength-related capabilities such as peak force and rate of force development [16] we attribute our results, which are different from the literature to the difference in our performance criteria.

Previously, a training time of 8:00 has been analysed to examine the impact of time of day on physical performance variables [15,17]. In our study, the average start time of the Morning training sessions was 11:37:30 ± 00:21:13. Some new research focuses on the chronometric tests as a novel approach, which is since the main predictor of peak performance is the time since entrained awakening, and not time of day [18]. They concluded that it does not matter at which time of the day is the best performance of a person, but how many hours after waking up is a performance or competition carried out. Therefore, physiological parameters such as levels of cortisol and melatonin should be added to the parameters examined in our study.

An important performance criterion for elite athletes is total sleep time [18]. A meta-analysis study by Roberts et al. identified that morning training sessions resulted in an earlier wake up time (2.5 hours earlier) the next day. Similarly, reduced sleep has been noted via later sleep-time due to social engagements scheduled in the evening. Previously, the so-called 'forbidden zone'-a period of heightened arousal mediated by the body's circadian rhythms generally decreases sleep propensity between 20:00 and 22:00 [19]. Although in the current study total hours of sleep was not documented, given the clear link with circadian biology, future studies should consider the impact on scheduling and physical performance. A further limitation of this study is the absence of chronotype profiling within the cohort. For example, Roveda et al. [20]. emphasized that chronotype was noticed to affect agility, aerobic endurance, and explosive power [21-24].

Practical Applications and Future Studies

The findings of this study emphasise that MD-1 training may be optimally timed in the morning to maximise within-session physical performance. Coaches should note different aspects of physical performance may be affected by circadian rhythms when planning and designing sessions. Nevertheless, our analysis of the circadian rhythms in soccer would suggest that the performance of skill-based movements and those requiring complex competitive strategies decisions and the delivery and recall of coaching instructions are best completed in the morning in elite-level soccer.

Although this is a novel study in this area of professional soccer, future studies are encouraged to further investigate the relationship between circadian and performance. One of the limitations of the study was that it did not include player chronotypes. Future recommendations would be to include the player chronotypes of the elite-level in studies, whilst determining and comparing sleep time across the cohort.

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DOI: 10.19080/JPFMTS.2023.10.555779

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