Time of Day Effect on Repeated Sprint Ability, Aerobic Capacity and Physiological Responses in Team-Sport Athletes

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Abstract

The aim of this study was to examine the time of day effect on aerobic capacity, repeated sprint ability and physiological responses in team-sport athletes. Ten male athletes (age: 21.60 ± 1.42, height: 185.10 ± 7.30cm, body weight: 82.15 ± 4.88, % body fat: 12.98 ± 2.39) who regularly exercise and engage in team sports, participated in this study voluntarily. Athletes were subjected to Repeated Anaerobic Sprint Test and 20m Shuttle Run Test at three different times of the day in the morning (09.00-10.00), afternoon (12.00-13.00) and evening (16.00-17.00) at two-day intervals. As a result of Repeated Measures ANOVA, statistically significant differences were observed when comparing body temperature $(F_{(2,18)}=10.042, p=.001)$, vertical jump height $(F_{(2,18)}=9.216, p=.005)$, maximal power $(F_{(2,18)}=9.059, p=.002)$, mean power $(F_{(2,18)}=8.617, p=.002)$, minimum power $(F_{(2,18)}=7.120, p=.002)$, aerobic capacity $(F_{(2,18)}=6.967, p=.006)$, maximal heart rate $F_{(2,18)}=6.859, p=.006)$, and blood lactate levels after exercise tests $(F_{(2,18)}=6.041, p=.010)$ measured at morning, afternoon and evening time periods. According to Bonferroni test results; body temperature, vertical jump height, maximal power, aerobic capacity values were found to be statistically higher in the evening hours than the morning hours $(p<0.05)$. Blood lactate level and maximal heart rate were increased significantly after tests in the evening $(p<0.05)$. In this study, factors such as having a good sleep quality, body temperature and circadian type can be shown as reasons for the performance of the athletes to be good in the evening compared to the morning hours. In conclusion, while planning the athletic training programs, it is thought that it is important to perform training which include aerobic and anaerobic capacity, explosive power and jumping exercises in the evening hours because of the significant increases in performance of the athletes

Keywords: Team Sport, Aerobic Capacity, Anaerobic Capacity, Blood Lactate, Different Time of Day

Introduction

Many biological functions vary cyclically over a 24-hour period depending on the darkness and temperature. These cycles are defined as circadian rhythms (Reilly, 1990; Punduk et al., 2005). The human circadian rhythm is governed by a circadian clock consisting of two separate components: central (main) and biological clocks (Hower et al., 2018). The main clock in the brain coordinates all the biological clocks in one day and ensures that the clocks are synchronized. Suprachiasmatic Nucleus (SCN), called the main clock, consists of approximately 20,000 neurons. SCN is located in a part of the brain called hypothalamus and receives direct input from the eyes. Biological clocks are an organism's innate timing device. It takes place in almost all tissues and organ systems in the body. They consist of certain molecules (proteins) that interact with cells in the body. Circadian rhythm is closely related to biological clocks. Biological clocks produce circadian rhythms and regulate their timing. Impaired or abnormal circadian rhythms may cause biological clocks to run slowly or rapidly (Hower, 2018; NIH, 2017; Winter et al., 2007). Oscillations in physiological processes responsible for both internal and external stimuli affect the circadian rhythm (Touitou and Haus, 1992; Atkinson and Reilly, 1996). Circadian rhythm synchronized to a 24-hour light /dark cycle is affected by various physiological and behavioural processes such as core body temperature, body hormone secretion, melatonin, autonomic nervous system, sleep /wake state and cognitive functions (Mizuno, 2014). Environmental factors such as physical activity and light types also affect circadian rhythm (Hower et al., 2018). Youngstedt et al., (2016) suggested that bright light was a stronger zeitgeber than exercise on circadian rhythm. Although the relevant mechanisms are not fully understood, there is growing evidence that exercise has significant effects on sleep/wake cycles and circadian clock modulation in human (Morgan et al., 2015).

A large number of team games require participants to repeatedly produce maximal or near maximal sprints of short duration with brief recovery periods (Wadley and Le Rossignol, 1998). The ability to produce the best possible average sprint performance during a series of sprints separated by short rest periods is called Repeated Sprint Ability (RSA). One of the best way to train RSA is to perform Repeated Sprint Test (Bishop et al., 2004; Bishop et al. 2011). Wadley and Lee Rossignol (1998) indicated that phosphagen system was the main energy contributor for Repeated Sprint Rest (Wadley and Le Rossignol, 1998). The depletion of phospho-creatinine (PCr) reserves and the ability to buffer H^+ has often been mentioned as a limiting factor for the performance of repeated sprinting (Bishop et al., 2004). Aerobic power which is the ability to produce aerobic energy at a high rate is characterised by VO_2max and aerobic capacity refers the ability to sustain for prolonged period (Bangsbo and Michalsik, 2002). High aerobic fitness or aerobic capacity level is a prerequisite for superior anaerobic performance during continuous intermittent activities (Aziz et al., 2000). Da Silva et el., (2010), Jones et al., (2013) demonstrated that Repeated Sprint Ability was more strongly correlated with aerobic power or aerobic capacity. Having a good aerobic capacity increases yield in short-term high-intensity activities over a prolonged period of time (Jones et al., 2013).

The different physiological and psychological features which were mentioned above, associated with superior athletic performance in team and individual sports vary according to the time of day. These features show ups or downs at maximum or minimum levels at particular times of the day (Cappaert, 2009). It was seen that the most important components of athletic performance reached peak values in the evening hours depending on the body's increasing temperature (Atkinson ve Reilly, 1996; Vitosevic, 2017). In the literature, there are different results in the studies examining the effect of circadian rhythm on the important

physiological properties. The studies in literature showed that Repeated Sprint Ability (Chtourou et al., 2018; Lopez-Silva et al., 2018; Pullinger et al., 2018; Racinais et al., 2005), anaerobic (Kin-Isler, 2006; Souissi et al., 2007; Gholamhasan et al., 2013; Souissi et al., 2010) and aerobic capacity performance (Chin et al., 2015; Chtourou and Souissi, 2012; Hammouda et al., 2013; Zghibi et al., 2018), vertical jump height (Chtourou et al., 2013; Chtourou et al., 2018; Heishman et al. 2017), blood lactate level (Kin-Isler, 2006; Chin et al., 2015), body temperature (Chin et al., 2015), agility, speed and explosive force (Rai and Tiwari, 2015) were higher in the evening hours compared to morning hours. In some studies, different time period of the day had no effect on aerobic power (Bessot et al., 2006; Movaseghi et al., 2016), vertical jump height (Brown et al., 2008; Grant and Glen, 2018), blood lactate level (Dalton et al., 1997; Kin Isler, 2006). It is important to determine the most suitable time zones of the athletes in order to achieve the highest level of athletic performance, to obtain better yields from the training and to better prepare for competitions. The aim of this study was to investigate whether different time periods of the day cause changes in Repeated Sprint Ability, Aerobic Capacity, and Physiological Responses of the in team-sport athletes.
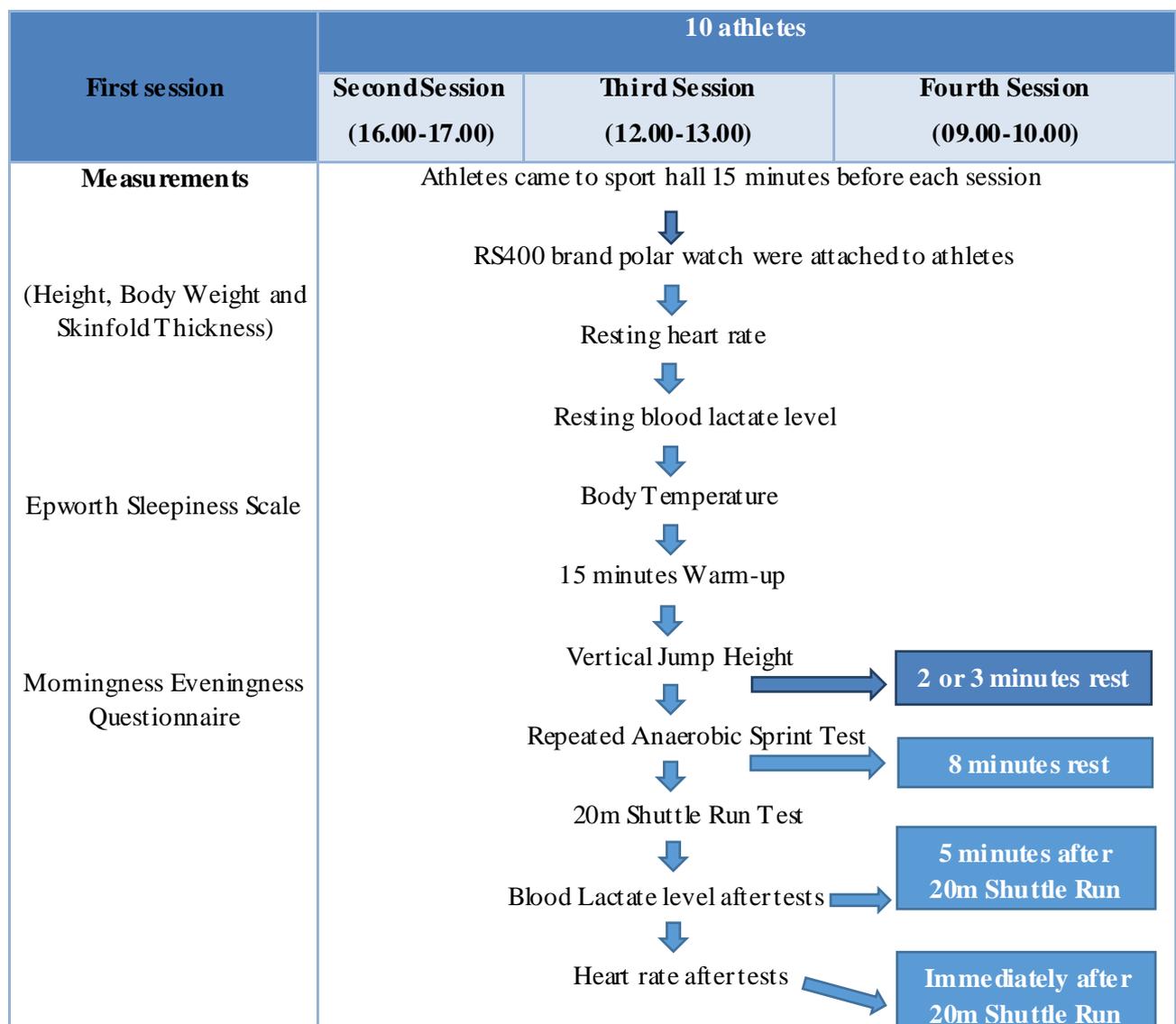
Methods

Participants

Ten male athletes who study Faculty of Sport Sciences in Mugla Sitki Kocman University, regularly exercise 3 days a week and engage in team sports (volleyball and basketball), participated in this study voluntarily. Prior to the study, the permission was obtained from the M.S.K.U Human Research Ethics Committee (Decision no: 25, Protocol no: 25). Athletes were informed by pre-interview about content and methodical model of the study in detail. Then, they signed an Informed Consent Form. The measurements of the study were completed in 4 sessions with a minimum interval of 2 days between each session (Zagotta et al., 2009). For the first session, the height, body weight and skinfold thickness of the athletes were measured in the Physiology Laboratory of the Faculty of Sport Sciences. In addition, the participants completed the Epworth Sleepiness Scale and Morningness-Eveningness Questionnaire. For the second, third and fourth session, The Repeated Anaerobic Sprint Test and 20m. Shuttle Run Test were applied to the participants in the evening (16.00-17.00), afternoon (12.00-13.00) and morning (09.00-10.00), respectively (Chin et al., 2015). Heart rate and blood lactate values were recorded before and after the tests.

Collection of the Data

Firstly, the permission for the measurements of the study was obtained from the M.S.K.U Health, Culture and Sports Department. The measurements were performed in Sports Hall in May. During the test measurements, the subjects were informed that they should maintain their normal eating habits and avoid excessive fatty food intake. Before the 24 hours of each test session (second, third and fourth), athletes were warned that they should sleep for at least 8 hours, not to use any caffeine or stimulants, and not to perform high-intensity activity. They were also informed that they should receive light food before each test session.

During the second, third and fourth test session, below sequence was followed in data collection;

The athletes came to the sport hall fifteen minutes before each the test session. Firstly, RS400 brand polar watch was attached to athletes in order to determine resting heart rate, then body temperature and resting blood lactate levels were measured. The athletes are warmed with the trainer for 15 minutes. After warming up, the vertical jump height was determined. After completing the vertical jump test, athletes had a rest for 2 or 3 minutes and then Repeated Anaerobic Sprint test was applied to the athletes in the form of 5 athletes. Athletes had 8 minutes of rest between Repeated Anaerobic Sprint Test and 20m. Shuttle Run Test. (https://www.safa.net/wp-content/uploads/2017/06/FIFA-Fitness-Tests-English.pdf). After resting, they participated in 20m Shuttle Run Test. Fingertip blood lactate samples were collected within 5 minutes after the participant finished the 20m Shuttle Run Test (Chin et al., 2015) (Figure 1).

First session	10 athletes		
	Second Session **(16.00-17.00)**	**Third Session** **(12.00-13.00)**	**Fourth Session** **(09.00-10.00)**
Measurements	Athletes came to sport hall 15 minutes before each session		
	RS400 brand polar watch were attached to athletes		
(Height, Body Weight and Skinfold Thickness)	Resting heart rate		
	Resting blood lactate level		
Epworth Sleepiness Scale	Body Temperature		
	15 minutes Warm-up		
	Vertical Jump Height	→	**2 or 3 minutes rest**
Morningness Eveningness Questionnaire	Repeated Anaerobic Sprint Test	→	**8 minutes rest**
	20m Shuttle Run Test		
	Blood Lactate level after tests	→	**5 minutes after 20m Shuttle Run**
	Heart rate after tests	→	**Immediately after 20m Shuttle Run**

Figure 1. Visual Study Plan in Data Collection

Data Collection Tools

Body Weight and Height: The body weight and height were measured by Seca brand measurement tool (0.01 kg and 0.01 cm sensitivity) The data were written on the information form as centimetres and kilogram (Gunay et al., 2010).

Skinfold Thickness: Holtain brand skinfold calliper which applies a pressure of 10 g/sq mm at each angle, was used to detect the percentage of body fat. The measurements were taken from the right side of the participants while they were standing upright (Zorba and Saygin, 2013). In this study, the values obtained from 4 regions (biceps, suprailiac, subscapular, triceps) were calculated based on the Durnin-Womersley (1974) formula (http://www.linear-software.com/online.html).

Heart Rate: The heart rate values of the athletes during rest condition and after the tests were determined by Polar RS400, Finland.

Body Temperature: Body temperature of the athletes was measured by IR900 Gun Type Forehead Fever Meter Device.

Blood Lactate Analysis: The lactate accumulates in the muscles during the exercise. There is a time lag for the diffusion from active muscles and re-distribution within the body. To determine peak lactate concentration in the blood, samples should be taken at intervals during the first 5 to 10 min. of the recovery period (Astrand and Rohdahl, 1986). Nova Biomedical Lactate Plus (40828 brands) was used to evaluate the blood lactate concentration. In this study, fingertip blood lactate samples were collected during rest condition and within 5 minutes after the participant finished the 20m Shuttle Run Test (Chin et al., 2015).

Sargent Vertical Jump Test: The athlete stood side on to a wall and reached up with the hand closest to the wall. He kept the feet flat on the ground, the point of the fingertips was marked and recorded. The athlete then stood away from the wall and jumped vertically as high as possible using both arms and legs. He touched the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height was determined "score". This test was performed three times and the best score was recorded (Gunay et al., 2010)

Repeated Anaerobic Sprint Test: The anaerobic power and capacities of the athletes were determined by Repeated Anaerobic Sprint Test using photocell system. The Run-Based Anaerobic Sprint Test (RAST), developed by Draper and Whyte (1997) at the University of Wolverhampton in the UK in 1997, is a test protocol designed to measure anaerobic power and capacity (Zagatto et al., 2009). The test includes six sprints on a distance of 35 meters with a 10-second rest interval between each sprint. By measuring body mass and sprint times, it is possible to calculate the power in each sprint (Power=body mass x distance^2/time^3). It is widely used by exercise specialists to monitor the performances of athletes. For each athlete, the maximum power, mean power, minimum power, and fatigue index were calculated by entering the 6 sprints value of the calculation tool at https://www.brianmac.co.uk/rast.htm.

20 Meter Shuttle Run Test: 20m Shuttle Run test which is a field test, was used for the determination of MaxVO$_2$ or aerobic capacity. It is a 23-level test that starts with 8.5 km.s^{-1} (9 sec) and increases the running speed by 0.5 km.s^{-1} every 1 minute. The participant runs a round-trip of 20m. The running speed is controlled by a cassette player that emits a beep at regular intervals. The subjects were run in the determined lines on a 20-meter track and continued to test until they made two errors (Leger et al., 1988; Gunay et al., 2010). The

method developed by Ramsbottom et al. (1988) was used to convert the shuttle levels to MaxVO$_2$.

Morningness-Eveningness Questionnaire: The questionnaire, is a Likert scale type consisting of 19 questions, which determine the circadian type of the athletes, possible answers are given as 4 options. Each response option is clearly schematized. The timetable is used in the answer to the questions 1, 2 and 10. This ruler is divided into a 7-hour timeframe and is expressed in 15-minute sub-slices. The answer options of the other questions are in the form of boxes. For each question, the participants who scored different points according to the answer they were marked (between 1 and 4 score for the questions 3, 4, 5, 6, 7, 8, 9, 13, 14, 15 and 16; between 1 and 5 score for the questions 1, 2, 10, 17 and 18; between 0 and 6 score for the questions 11 and 19; between 0 and 5 score for the question 12). Five different circadian type classification is made according to the total scores obtained for 19 questions; "absolutely morning type" in the range of 70- 86 points, "close to the morning type" in the range of 59-69 points, "intermediate type" in the range of 42-58 points, "close to the evening type" in the range of 31-41, "absolutely the evening type" in the range of 16-30. The validity of the original questionnaire and the classification of the circadian type were tested with changes in body temperature (Punduk et al., 2005).

The Epworth Sleepiness Scale (ESS): The scale includes 8-item based on simple and self-report. The scale questions the general sleepiness level of the individual. It aims to evaluate the sleepiness level of individuals in eight different daily life situation (while reading a book, watching television, sitting quietly in a public place, traveling in a car, lying in the afternoon, talking to someone else, sitting quietly after lunch without alcohol, in a car that stopped in the traffic for a few minutes). The probability of individuals' falling asleep is graded between zero and three. According to this rating system: 0. Never happens 1. Occasionally happens 2. Medium frequency happens 3. It happens very often. The sum of the answers given to the 8 questions by individuals gives the sleep quality (Izci et al., 2008)

Data Analysis: All data obtained in the study were recorded in SPSS (version 18.0) program. The Shapiro-Wilk test was used to reveal the normality of the data. Once the assumption of normality was confirmed, Repeated Measures ANOVA was used to determine the differences of the parameters among three different time periods. Sphericity was determined by Mauchly's test. If any differences were detected, pairwise comparisons with Bonferroni Correction were used. The significance level was accepted as $p < 0.05$.

Table 1. The mean and standard deviation values of the age, height, body weight, skinfold thickness and body fat percentage of athletes

Variables	N	M.±S.D.
Age (years)	10	21.60±1.42
Height (cm)	10	185.10±7.30
Body Weight (kg)	10	82.15±4.88
Biceps (mm)	10	3.62±1.09
Triceps (mm)	10	7.76±3.01
Subscapula (mm)	10	10.91±2.14
Suprailiac (mm)	10	8.88±2.48
Body Fat (%)	10	12.98±2.39
Lean Body Mass (kg)	10	71.47±4.40

Table 1 shows that the mean and standard deviation values of age, height, body weight, biceps, triceps, subscapular, suprailiac, body fat (%), and lean body mass of athletes were 21.60±1.42 years, 185.10±7.30 cm, 82.15±4.88 kg, 3.62±1.09 mm, 7.76±3.01 mm, 10.91±2.14 mm, 8.88±2.48 mm, 12.98±2.39, 71.47±4.40 kg, respectively.

Table 2. Total scores of the questionnaire and scale answered by the ten participants

	Score	Classification		Score	Classification
Morningness-Eveningness Questionnaire Results	59	Close to the morning type	The Epworth Sleepiness Scale Results	2	Good
	54	Intermediate type		2	
	44	Intermediate type		2	
	60	Close to the morning type		4	
	39	Close to the evening type		5	
	39	Close to the evening type		4	
	37	Close to the evening type		8	
	51	Intermediate type		8	
	54	Intermediate type		9	
	35	Close to the evening type		2	

In Table 2, the results of the total score of the Epworth Sleepiness Scale and the Morningness-Eveningness Questionnaire of 10 athletes who participated in the study were given. According to the results of Morningness-Eveningness Questionnaire, it was observed that 4 athletes were close to evening circadian type, 2 athletes were intermediate circadian type, 2 athletes were close to morning circadian type. Athletes had a good sleep quality according to results of the Epworth Sleepiness Scale.

Table 3. Comparison of body temperature, resting heart rate, resting blood lactate level and vertical jump height measured in different time periods of the day

	Time of Day			F	p	Bonferroni
Variables	**09.00-10.00 (1)**	**12.00-13.00 (2)**	**16.00-17.00 (3)**			
Body Temperature (^{0}C)	35.75±.22	35.95±.19	36.20±.35	10.042	**.001***	1-3
Resting Heart Rate (beat/min.)	75.20±8.59	77.20±9.62	78.60±7.94	2.263	.133	N.S.
Resting blood lactate (mmol)	2.44±.81	2.45±.64	2.34±.44	.093	.911	N.S.
Vertical Jump Height (cm)	55.10±5.40	55.70±7.64	59.60±5.89	9.216	**.002***	1-3, 2-3

$p<0.05$, N.S.: Not significant

As shown in Table 3, according to the Mauchly's test results, the assumption of sphericity was $p = .629$ for body temperature, $p = .461$ for resting heart rate, $p = .399$ for resting blood lactate level, and $p = .377$ for vertical jump height. Therefore, Sphericity Assumed values

were taken into account. According to the results of Repeated Measures ANOVA; it was observed that different time periods of the day had a statistically significant effect on body temperature ($F_{(2,18)}$=10.042, p=.001) and vertical jump height ($F_{(2,18)}$=9.216, p=.002). The body temperature measured in the evening time period (16.00-17.00) was significantly found to be 1.25% higher than in the morning time period (09.00-10.00). The vertical jump height measured in the evening hours (16:00-17.00) was significantly 8.16% higher than in the morning and 7% higher than in the afternoon.

Table 4. Comparison of the maximum, average and minimum power, fatigue index, aerobic capacity, Heart Rate$_{post-tests}$ and Blood Lactate Concentration$_{post-tests}$, measured in different time periods of the day

Variables	Time of Day			F	p	Bonferroni
	09.00-10.00 **(1)**	**12.00-13.00** **(2)**	**16.00-17.00** **(3)**			
Maximum Power (W)	871.20±93.44	834.50±124.56	1012.30±75.59	9.059	**.002***	1-2, 2-3
Average Power (W)	773.80±122.49	698.70±122.42	894.90±99.54	8.617	**.002***	2-3
Minumum Power (W)	673.70±133.89	576.40±111.05	765.50±141.46	7.120	**.005***	2-3
Fatigue Index (W/sec)	6.43±2.18	8.01±3.93	8.36±3.72	1.040	.374	N.S.
Aerobic Capacity (ml/kg/min.)	38.46±7.49	39.53±6.02	46.20±3.69	6.967	**.006***	1-3, 2-3
Heart Rate$_{post-tests}$ (beat/min)	167.20±8.33	172.20±8.24	178.20±8.96	6.859	**.006***	1-3
Blood Lactate $_{post-tests}$ (mmol)	8.99±1.71	11.85±3.60	13.02±2.72	6.041	**.010***	1-3

*p<0.05, N.S.: Not significant

As shown in Table 4, according to the Mauchly's test, the assumption of sphericity was p = .361 for maximum power, p = .529 for average power, p = .789 for minimum power, p = .202 for fatigue index, p = .202 for aerobic capacity. .875, p = .696 for heart rate after the tests and p = .746 for blood lactate level after the tests. A statistically significant differences were observed when comparing maximal power ($F(2,18)$=9.059, p=.002), average power ($F(2,18)$=8.617, p=.002), minimum power ($F(2,18)$=7.120, p=.002), aerobic capacity ($F(2,18)$=6.967, p=.006), maximal heart rate after the tests $F(2,18)$=6.859, p=.006), and blood lactate levels after the tests ($F(2,18)$=6.041, p=.010) measured at morning (09.00-10.00), afternoon (12.00-13.00), and evening time periods (16.00-17.00). At the end of the Repeated Anaerobic Sprint Test, the maximum power values of the athletes in the evening hours were found to be 16.19% and 21.30% higher than in the morning and afternoon hours, respectively. It was observed that the average power value of athletes in the evening hours was 28.08% higher than in the afternoon hours. In the evening hours, the minimum power value of athletes increased by 32.80% as compared with the afternoon hours. The aerobic capacity of the athletes determined according to the 20m Shuttle Run Test result increased by 20.12% compared to the morning hours and by 16.87% compared to the afternoon hours. As compared with the morning hours, heart rate after the tests was 6.57% and blood lactate levels after tests were 44.82% higher in the evening hours.

Discussion

The aim of this study was to examine the time of day effect on Repeated Sprint Ability, Aerobic Capacity, and Physiological Responses in Team-sport athletes.

Body Temperature

The most important determinants of circadian rhythm are body temperature (Shephard, 1984). Body temperature in humans is regulated within narrow limits around 37 ° C (Waterhouse et al., 2005). It was observed that the body's core temperature is the lowest level at 04:30 in the morning, gradually increasing during the day and peaking at 18:00 in the afternoon (Vitosevic, 2017). The internal core temperature is regulated by nerve cells in the hypothalamus. The origin of the circadian rhythm of core temperature is mainly due to circadian changes in the rate of loss of heat through the extremities, mediated by vasodilation of the cutaneous vasculature (Waterhouse et al., 2005). According to the results of this study, it was observed that different time periods of the day had a statistically significant effect on body temperature ($F_{(2,18)}$=10.042, p=.001). The body temperature measured in the evening time period (16.00-17.00) was significantly found to be 1.25% higher than in the morning time period (09.00-10.00) (Table 3).

In the literature, it was observed that body temperature was higher in the evening than in other hours of the day (Hammouda et al., 2012; Jaraya et al., 2014; Konishi et al., 2016; Ozcelik and Guvenc, 2016; Boussetta et al., 2017). Reilly and Garrett (1998) reported that rectal temperature was 0.68^0C lower in the morning than in the evening hours. Pullinger et al., (2018) and Racianis et al., (2005) stated that muscle and rectal temperature was found to be higher in the evening hours than in the morning hours. Zghibi et al., (2018) found a statistically significant difference between body temperature (36.9 ± 0.2) measured at 17.00 hours and body temperature (36.3 ± 0.4) at 08.00 hours. It was observed that the body temperature was higher in the evening hours. Ferchichi et al., (2015) found that the oral temperature was higher in the evening (17.00-19.00) than in the morning (07.00-09.00am). The oral temperature was 36.1 ± 0.2 °C in the morning and 36.8 ± 0.2 °C in the evening. The results of the above studies are in line with the findings of this research. Starkie et al., (1999) reported that elevated intra-muscular temperature increased muscle glycogen use and didn't cause any change in phosphogenous system. They stated that increase in carbohydrate utilization occurred as a direct effect of an elevated muscle temperature. Manfredini et al., (1998) stated that the circadian rhythm of body temperature may be originated by fluctuations in the heat loss mechanism rather than heat production due to noradrenergic increase. There is a positive relationship between body temperature and athletic performance A high body temperature can increase metabolic reactions, increase the extensibility of connective tissue, decrease muscle viscosity, and increase the transmission speed of action potentials (Shaward, 1984, quoted in Hammouda et al., 2012). Thun et al., (2015) examined 113 articles in their review and showed that athletic performance was the best around when core body temperature was typically the highest.

Vertical Jump Height

A statistically significant difference was detected when comparing the vertical jump height measured in different time periods of the day (F (2,18) = 9.216, p =.002). The vertical jump height measured in the evening hours was 8.16% higher than in the morning hours and 7% higher than in the afternoon hours (Table 3). The studies examining the effect of different time periods on vertical jump in different sports branches are available in the literature. There

are conflicts results in these studies. Pallares et al., (2014) found that the elite young swimmers had a statistically significant 4.3% higher vertical jump height in the morning (10.00am) than in the evening (18.00pm). Another study conducted by Lopez-Samanes et al., (2016) on elite tennis players, they found a 4.5 ± 5.1% higher vertical jump height in the evening (16.30) hours than in the morning (09.00). Heishman et al., (2017) ascertained that basketball players had a lower vertical jump performance in the morning hours (07.00-09.00am) as compared with afternoon hours (13.45-16.00). They reported that vertical jump score in the morning and in the afternoon hours were 58.8±1.3cm and 61.9±1.6cm, respectively. Similar vertical jump score was found in this study. In a study conducted Boussetta et al., (2017) on 11 football players with a mean age of 21.8, the results revealed that diurnal variation was found in short-term maximal tests (vertical jumping test). The vertical jump height was reported to be significantly better in the evening hours. Chtourou et al., (2013) indicated that circadian rhythm affects squat-jump (SJ) and countermovement-jump performance. The jump performances of soccer players were better at 17:00 hours in the evening than at 07:00 hours in the morning. They observed more increase in squat-jump and countermovement-jump performances due to the increase of oral temperature in the morning after dynamic warming as compared with evening hours. Brown et al., (2008) investigated the time of day effect on vertical jump performance of 8 men and 8 women rowers. They reported that there was no statistically significant difference in high jump performance between morning hours (05.00-07.00 am) and evening hours (16.30-18.00pm). They also stated that the chronotype did not have an impact on the high jump performance. Grant and Glen (2018) stated in their study on 12 swimmers that there was no statistically significant difference in the vertical jump performances measured between 05:30 - 6:30 in the morning and 17:30-18:30 in the evening. Chtourou et al., (2018) ascertained that the vertical jump height of the elite judoists measured in the evening hours (17.00) was not different from the vertical jump height measured in the morning (07.00).

Repeated Anaerobic Sprint Test

The different time periods of the day had a statistically significant effect on maximum power $F_{(2,18)}=9,059$, p<.002), average power ($F_{(2,18)}=8,617$,p<.002), and minimum power ($F_{(2,18)}=7,120$, p<.002). At the end of the Repeated Anaerobic Sprint Test, the maximum power values of the athletes were found to be 16.19% and 21.30% significantly higher than in the morning and afternoon hours, respectively. The average power value measured in the evening hours was 28.08% higher than afternoon hours. In the evening time period, the minimum power value increased by 32.80% compared to afternoon hours (Table 4). There were different results in the literature about the time of day effect on the anaerobic power or capacity in different sports branches. According to the literature, peak power performance, anaerobic power and anaerobic capacity were found to be higher in the exercises or tests performed in the evening than in the morning (Heishman et al., 2017; Ozcelik and Guven, 2016). Pullinger et al., (2018) observed that $10 \times 3s$, 30-sec rest Repeated Sprint Performance (distance covered, average power, and average velocity) of male athletes at performing different intensities on the treadmill was higher in the evening hours (17.30pm) than in the morning hours (07.30am). They also found that increasing the morning rectal temperature (passive warm-up) to the evening rest values or optimal values (38.5^0C) did not lead to a positive change in Repeated Sprint Test performance. It was indicated that increasing the rectal temperature in the evening by a passive warm-up to the optimal value (38.5^0C) caused a decrease in the total distance. Chtourou et al., (2013) found that the peak power, average power, and fatigue index values of 10 soccer players were higher in the evening hours (17.00)

than in the morning hours (07.00). Racinais et al., (2005) evaluated the repeated sprint test performance (5x6sec, 24-sec rest interval) of 9 active physical education and sports students in the morning hours (07.00-09.00) and in the evening hours (17.00-19.00). They expressed that peak power for the first sprint was higher in the evening hours (958 ± 112W) than in the morning hours (915±133W). Higher power decrement was occurred in the evening during the 5x6sn sprint test. They pointed out that a higher power decrement across the Repeated Sprint test which could be linked with the significant increase in blood lactate concentration from morning to evening. Souissi et al., (2013) found out that muscle strength, muscle power, average power, and peak power of the judoists were higher in the evening hours (16.00) than morning hours (09.00). They also stated that these diurnal changes were impaired in case of insomnia. Zarrouk et al., (2012) investigated the effect of time of day on the 4-thigh muscle's electromyographic activity level and muscle power during the Repeated Sprint Test (5X6sec, 30sec rest interval) on the bicycle ergometer. As a result; total work and peak power decrement were higher in the evening (18.00) than in the morning (06.00). They showed that peak power during the first 3 sprints was greater in the evening hours than morning hours. Although muscle power and fatigue showed diurnal fluctuations during the Repeated Sprint Test, It was reported that the EMG activity of thigh muscles was not dependent on the time of day. They asserted that diurnal improvement in muscle power and fatigue is not due to a change in neural drive but rather due to an improvement of the muscle contractile properties in the evening. Racinais et al., (2010) applied to a repeated sprint test (10X6sec, 30sec rest interval) on a bicycle ergometer for 8 participants in the evening (17.00-19.00) and morning hours (08.00-10.00). The peak power output in the first 3 sprints was higher in the evening and higher power decrement was detected for 10 sprints. High power decrement in the evening hours was indicated as a result of high power output in the first three sprints. Chtourou et al. (2018) examined the time of day effect on elite judoists. They stated that Repeated Sprint Test performance (total sprint time, sprint fatigue index) of the athletes was not sufficiently dependent on the time period of the day. Grant and Glen (2018) showed that the different time period of the day did not have a statistically significant effect on 800 m swimming performance. The study was conducted by Pallares et al. (2014) on elite young swimmers, they determined no statistically significant difference between the peak power values measured after Wingate test in the morning (10.00) and evening (18.00) hours. The peak power increased by 3.2% in the evening hours compared to morning hours.

Aerobic Capacity

It was observed that time of day had a statistically significant effect on aerobic capacity. The aerobic capacity of the athletes determined according to the 20m shuttle run test result increased by 20.12% compared to the morning hours and by 16.87% compared to the afternoon hours (Table 4). Cappaert (1999) stated that maximal oxygen consumption (aerobic capacity) peaked between 15.00-20.00 hours. Zghibi et al. (2018) applied to the Yo-Yo Intermittent-1 test at 17.00 and 08.00 hours on different days. They denoted that the young subjects had significantly higher maximal aerobic velocities and offensive capacities during the test in the evening hours (17.00pm). Seo et al. (2013) suggested that diurnal and hormonal changes created a difference in physical performance depending on the time of day. The study was executed by Movaseghi et al. (2016), they subjected active women to an increased exercise protocol on the bicycle ergometer at three different times of the day. (09.00, 14.00, 18.00), they emphasized that the time period of the day did not cause any statistically significant effect on the maximal oxygen utilization capacity. It was also found that lung function was better in the evening. Ferchichi et al. (2015) emitted that maximal swimming

performances of swimmers were better in the evening than in the morning. Swimming speed, stroke rate, stroke length and motor organization parameters were found better in the evening hours. This positively affected the swimming performance. Boussetta et al. (2017) and Hammouda et al. (2012) stated that Yo-Yo Intermittent-1 test soccer players (mean age: 21.8) were found to be better in evening hours than in the morning hours

Heart Rate and Blood Lactate Level after tests

Statistically significant differences were observed when comparing heart rate F(2,18)=6,859, p<.006), and blood lactate levels after the tests (F(2,18)=6,041, p<.01) measured at morning (09.00-10.00), afternoon (12.00-13.00) and evening time periods (16.00-17.00). The heart rate and blood lactate levels of athletes after tests were found to be 6.57% and 44.82% significantly higher in the evening hours, respectively (Table 4). The heart rate varies between 5% and 15% within a 24-hour period an acrophase of around I5.00 hours (Atkinson and Reilly, 1996). The results of this study were in parallel with the result of Cruz et al. (2014) and Reilly and Garret (1998). They also reported that heart rate reached to higher values during the evening exercises. Ozcelik and Guvenc (2016) reported that the heart rate recorded during the Wingate Anaerobic Test was lower in the morning than in the evening hours. Chin et al. (2015) indicated that blood lactate values of male athletes in the morning, afternoon, and evening hours after 20m shuttle run test were found to be 12.27 ± 2.9mmol, 13.33 ± 2.9mmol, 12.28 ± 4.2mmol, respectively. They reported that circadian rhythm had no effect on blood lactate values. Racinais et at. (2005) applied to the Repeated Sprint Test on 9 active physical education and sports students in the evening hours (17.00-19.00) and morning hours (07.00-09.00). They defined that heart rate and blood lactate level of participants during the Repeated Sprint Test were higher in the evening hours. The blood lactate level of participants in the evening and morning hours was found to be 13 ± 3mmol /L and 11 ± 3mmol /L, respectively. The heart rate of participants in the evening and morning hours was found to be around 170 beat/min. and 155 beats/min., respectively. In a study conducted by. According to Astrand and Rohdahl (1986), the circadian rhythm of the blood lactate concentration can be partly explained by the increased body temperature. Higher body temperature during exercise results in faster progression of metabolic processes in cells. For each degree of temperature augment the metabolic rate of the cell increases by about 13%. This augments in body temperature also increases the activity levels of glycolytic enzymes such as lactate dehydrogenase and phosphofructokinase. The augment of these enzymes in relation to body temperature increases lactate production and clearance and this allows the athletes to work at higher lactate tolerance and higher exercise intensity (Dalton et al., 1998; Forsyth and Reilly, 2004). In this study, the athletes reached higher blood lactate levels after the tests and also showed better performance in the tests in the evening hours as compared with the morning hours. This can be explained by Astrand and Rohdahl (1986). Ozcelik and Guvenc (2016) suggested that evening hours might be more appropriate in terms of physical performance tests and competitions that should be at the highest level of performance.

Conclusion and Recommendation

In conclusion, the body temperature, vertical jump height, anaerobic capacity, and aerobic capacity of the athletes were found to be higher in the evening than morning and afternoon hours. In addition, the athletes reached higher heart rate and blood lactate levels in the evening tests. Based on these findings, it was observed that the athletes forced themselves more in the tests performed in the evening hours and reached the point of exhaustion later. In

this study, factors such as having a good sleep quality, high body temperature and chronotype type can be shown as reasons why athletes' performances are better in the evening than in the morning hours. There were some limitations to this study. Food consumption records of athletes were not recorded before and during test sessions. In this study, athletes firstly were subjected to Repeated Anaerobic Sprint Test and then 20m Shuttle Run Test at each exercise sessions. Blood lactate measurements were not performed after Repeated Anaerobic Sprint Test. Blood lactate measurements of the athletes were collected during rest and after 20m Shuttle Run Test. It can be shown as other of the limitation of this study. In future studies, these tests can be performed on different days. While planning the athletic training programs, it is thought that it is important to perform training which include aerobic and anaerobic capacity, explosive power and jumping exercises in the evening hours because of the significant increases in performance of the athletes. In further studies, by increasing the number of samples, the athletes should be classified according to chronotype, the evening and morning performances of the morning types and the evening and morning performance of the evening types should be determined and compared.

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Conflict of Interest

The authors have not declared any conflicts of interest.

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