



Endurance Performance According to Circadian Cycle

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ABSTRACT The aim of this study was to investigate the endurance performance according to the Circadian Cycle. For this aim, 38 male students studying at the Faculty of Sports Sciences (age between 20-27 years) participated in the study. 20 m Shuttle Run test was used to measure the aerobic endurance of the performance. The measurements were taken in the morning (09:00am), afternoon (2:00pm) or evening (7:00pm) time. The test sessions were performed in a random order. For the statistical analysis Friedman Two Way Variance analyses and Wilcoxon Signed Rank test were used. The results of the study showed that the number of shuttles were found to be higher in the afternoon than in the morning time ($p < 0.0167$). Although there is no statistically significant difference, the number of shuttles were found more in the afternoon than the number of shuttles in the evening. As a conclusion, the best aerobic performance was performed in the afternoon. Due to the presence of such a difference, the measurement times have been noted for future scientific studies.

INTRODUCTION

Cyclic changes in humans have been observed for centuries. There is an order and rhythm in the universe and in our world, which is a part of the universe, while there is a biological rhythm in the living beings on Earth (Waterhouse 1999). Cyclic changes which repeat themselves regularly within specific intervals in a given time period are called the biological rhythm. There are a few main rhythms we are under the effect of in our daily lives. These are the ultradian, circadian, infradian and circannual rhythms. Changes which are formed within a solar day are known as the circadian rhythm (Reilly et al. 2000). In other words, the circadian rhythm can be defined as the physiological changes that take place within a time period of 24-hours (Reilly 1990). Circadian rhythm is under the control of the suprachiasmatic nucleus (SCN) placed in the frontal hypothalamus of our brain. Circadian rhythm is also called the biological clock. This clock helps the organism to adapt to the environment and is responsible for the adjustment of sleep and wake pattern (Dunlap 1999; Walisser and Bradfield 2006; Hastings et al. 2007; Hunt and

Sassone-Corsi 2007; Kondratov 2007; Sancar et al. 2010).

Melatonin is a natural neurotransmitter. Melatonin, which is released from the pineal body, plays a vital role in the adjustment of the body clock. It has a role in a great number of biological and physiological adjustments in the body. It is a hormone which is effective on the human biorhythm (circadian rhythm). Its main duty is to keep the biological clock of the body and adjust its rhythm. Another well-known function of Melatonin is its contribution to the renewal of the cells and the immune system (Claustrat et al. 2005; Ratzburg 2013).

The association of the circadian rhythm with a great number of physiological variables in a sportive performance has attracted the attention of the researchers and it has been researched extensively. Studies have found circadian changes in maximal aerobic strength (Hill et al. 1992; Hill 1996), heart rate (Akkurt et al. 1996; Gunes et al. 1998; Reilly and Brooks 1986), blood pressure (Gunes et al. 1998; Reilly et al. 1984) and the central body heat (Reilly and Brooks 1986). In addition, age, type and intensity of exercise, jet-lag effect, sleeplessness and training time have also been found to affect the aforementioned daily changes (Reilly et al. 2000).

Understanding the circadian rhythm in sport performance is an important factor both for the athletes and the coaches and it can have important impacts on the short and long term success of an athlete or a team (Cappaert 1999). Indirect

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evidence about the presence of the circadian rhythms comes from the analysis of the hours athletes show their best and worst performance in *real sport* events (Atkinson and Nevill 2001). There is a circadian variation even in the previous assessments of performances which have broken world records (Atkinson et al. 1999), world records are broken by competing athletes in the early hours of the evening when the body temperature is the highest. A series of studies have emphasized that such retrospective researches should be interpreted carefully (Reilly et al. 2000; Atkinson and Reilly 1996).

If the sport performance varies, based on the time during the day under normal daily conditions, then this has a direct effect on the athlete. This effect causes the understanding of the circadian rhythm to become an important factor both for the athletes and for the coaches in terms of application (Cappaert 1999). There is also an impact on training, where the motivational climate of competitive stress is absent, and the training stimulus is highly dependent on the athlete's input of effort (Drust 2005).

Except for studies which show that aerobic endurance varies based on the circadian rhythm, there are also studies which state that circadian rhythm has no effect on the aerobic endurance. This study analyzes whether circadian rhythm has an effect on the aerobic performance and at the same time it also analyzes what time is more effective. Within this context, in this study, aerobic performance measurements were made at different times of the day in order to find out the time when coaches can impart more effective training.

METHODOLOGY

Samples

A total of 38 male students between the ages 20 and 27 studying at Ondokuz Mayıs University Yasar Dogu Faculty of Sport Sciences participated in the study voluntarily. The weights and

heights of the subjects were measured with SECA trademark measuring device. In order to get reliable results from the measurements, 20 m shuttle run test was explained and demonstrated in practice to the subjects. Care was taken for the subjects not to have any training and to rest on the day of the test.

Study Method

The subjects were tested during 3 different times of day each separated by 2 days: in the morning (9:00am), in the afternoon (2:00pm) and in the evening (7:00pm). The subjects were divided in three groups of 12-13 randomly and measurements were made on different days and at different times as shown in Table 1. The orders of the 3 times were selected randomly to prevent an order effect.

Performance Measurement

20m Shuttle Run Test

In this test, the running tempo is adjusted with the help of a signal generator electronic device on a straight and linear track and the person runs continuously between the two lines with a running tempo adjusted to the sound of the beep. Each 20 m the subjects run is recorded as one shuttle. The running speed starts with 8 km/h and increases 0.5 km/h every minute. On both the sides of the running track, there is a 2 meter area inward from the 20 m lines. When the beep sound comes, the subjects need to have caught the 2 m line and turn by touching the 20 m line. The test for a subject who makes 2 consequent mistakes ends and the number of shuttles is recorded.

Statistical Analysis

According to Kolmogorov Smirnov test, the data were not found to be normally distributed. Median were found to be unequal with the Fried-

Table 1: Grouping the subjects and measurement hours

Subjects	N	Measurement and hours		
		9:00am	2:00pm	7:00pm
1. Group	12	1. measurement	3. measurement	2. measurement
2. Group	13	2. measurement	1. measurement	3. measurement
3. Group	13	3. measurement	2. measurement	1. measurement

man test ($p < 0.05$), for the post hoc multiple comparison, the level of significance was reduced ($0.05/3 = 0.0167$) and Bonferroni corrected Wilcoxon Signed Rank test was applied.

The average weight of the subjects was 70.38 ± 7.97 kg, the average height of the subjects was 171.73 ± 6.11 cm, while the average body mass index of the subjects was 23.93 ± 3.02 kg/m² (Table 2).

When the aerobic performance values based on the circadian rhythm were analyzed in Table 3, it was found that the highest average of the shuttles were at 2:00 pm (92.55 shuttles) in the afternoon, 7:00 pm (88.55 shuttles) and at 9:00 am (85.44 shuttles) respectively. In addition, performance values measured in the afternoon were found to be significantly higher than those measured in the morning ($p < 0.0167$).

DISCUSSION

The researchers study analyzes whether aerobic endurance value differed based on the circadian rhythm. To this end, aerobic endurance measurements were made in the morning (9:00 am), afternoon (2:00 pm) or evening (7:00 pm). The hour with the best endurance values was found to be 2:00 in the afternoon, 7:00 in the evening and 9:00 in the morning, respectively. In addition, performance value measured in the afternoon was found to be significantly higher than that measured in the morning ($p < 0.0167$). The researchers' findings coincide with the results of the previous studies (Hill et al. 1992; Torii et al. 1992; Hill 1996; Souissi et al. 2007).

Hill et al. (1992), evaluated the effect of the time of the day on performances of high-intensi-

ty, constant-power cycle ergometer. They found that the total work performed was 9.6 percent greater in the afternoon when compared to the morning. The greater amount of work in the afternoon was associated with a 5.1 percent higher aerobic power and a 5.6 percent larger anaerobic contribution.

The study of Torili (1992), researched the circadian effects of an aerobic training programme who exercised at different times of day. Each group performed a 30 minutes percent 60 max VO_2 cycle ergometer exercise in the morning (09:00-09:30), afternoon (15:00-15:30) or evening (20:00-20:30). After four weeks the afternoon group showed a significant increase in the estimated max VO_2 . Their results suggest that aerobic training is most effective in the afternoon.

In the study of Hill (1996) subjects performed exhaustive exercise at about 08:00 am and 16:00 pm with the order of testing assigned randomly. They found that time to exhaustion was 9 percent greater and peak VO_2 was 7 percent higher in the PM than in the AM. They added that there is a time of day on VO_2 kinetics, with the aerobic system responding faster in the PM than in the AM (Hill 1996).

Souissi et al. (2007) evaluated the effects of the time of the day on aerobic contribution during a high intensity exercise. Peak power, mean power, total work done and VO_2 increased significantly from morning to afternoon during the Wingate Test. Their results indicated that the time of day effect on performances during the Wingate Test is mainly due to better aerobic participation in energy production during the test in the afternoon than in the morning.

Table 2: Height, weight and body mass index values of the subjects

	<i>N</i>	<i>Mean</i>	<i>Std. deviation</i>	<i>Min</i>	<i>Max</i>
Weight (kg)	38	70.38	7.97	54	86
Height (cm)		171.73	6.11	156	187
BMI (kg/m ²)		23.93	3.02	17.43	29.76

Table 3: Aerobic performance test (20m shuttle run) values of the subjects in terms of circadian rhythm

<i>Running time</i>	<i>Mean (shuttles)</i>	<i>Std. deviation</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>p</i>
9:00 am (a)	85.44	12.90	84	64.00	110.00	b>a*
2:00 pm (b)	92.55	14.53	92	66.00	120.00	
7:00 pm (c)	88.55	14.42	85	69.00	118.00	

* $p < 0.0167$

Studies were found in literature which compared only the performance values in the morning and in the evening (Nicolas et al. 2008; Hammouda et al. 2013; Hill 2014). For example Nicolas et al. (2008) examined the time of the day effects on the muscle fatigue and the recovery process following an isometric fatiguing constriction. Their results showed that under the pre-test condition, PT (peak torque) developed at 18:00h was higher than at 06:00h.

Hammouda et al. (2013) investigated the diurnal variation in the footballers' performance during the Yo-Yo intermittent recovery test associated with biochemical responses. Core temperature and performance during the Yo-Yo test increased from the morning to the evening without any significant time-of-day effects on the peak heart rate and rating of perceived exertion (RPE). More over the pre and post Yo-Yo test biochemical parameters were higher at 17:00h than 07:00h. Their finding suggests a possible link between the diurnal fluctuation of the metabolic responses and the related pattern of specific endurance performance in the footballers. Therefore, the higher biochemical responses observed in the evening could explain, partially, the greater performance and metabolic solicitation at this time of day.

In the study of Hill (2014), it is concluded that modest morning-evening differences in maximal oxygen uptake, anaerobic capacity, and oxygen uptake kinetics conflate to produce markedly longer performances in the evening than in the morning.

There are also some studies which do not support the results of the current study. Results of different studies have shown that the results of activities done at different times of the day may change. Beck and Gobatto (2013), determined that, the favorable time of day for aerobic capacity and performance assessment and hematological parameters was at 20:00h (dark period), which is associated with the wakefulness period of the assessed animals. Shiotani et al.'s (2009) study findings suggest two-month aerobic exercise exerts beneficial effects on the circadian rhythm of the heart rate, especially in the morning. Souissi et al. (2012) determined that a six-week training program increases muscle strength and power especially after training in the morning hours and the magnitude of gains was greater at the time-of-day-specific training than at other times. They found that the improve-

ment of these performances was greater after morning than evening training. According to the results of the conducted study, the researchers recommend the afternoon hours for aerobic training. While comparing performance in the morning and evening hours, Sousissi et al. (2012) did not analyze the morning hours. The reason why the results of Sousissi et al. (2012) are different from the results of the current study may be because they did not evaluate the afternoon hours.

Hatfield et al. (2016), examined the effects of the circadian variations on the muscular power output and hormonal changes in men. Testing occurred at 4 different times of the day (04:00, 10:00, 16:00 and 22:00 hours). Testosterone and cortisol hand dynamometer strength, heart rate, mental readiness, bench press throws and squat jumps, power, and force were measured each time. Their results showed that high force and power exercises using bench press throw or squat jump may be performed any time of day without detrimental decreases in acute performance.

CONCLUSION

To conclude, it was found that the best performance which includes activities of aerobic endurance has been shown in the afternoon hours. Due to such a difference, future studies should indicate the measurement hours.

RECOMMENDATIONS

Due to the presence of such a difference, the measurement times have to be noted in the future scientific studies. Aerobic trainings are recommended to be conducted in the afternoon hours.

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