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Investigation of the Changes in Performance Measurements Based on Circadian Rhythm

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ABSTRACT The aim of this study was to investigate the circadian changes in some physical performance measurements. A total of 25 male volunteer university students (athletes) participated in the study. The athletes were subjected to simple and multiple reaction time, flexibility, vertical jump, dynamic and static balance tests on three different days and periods of time (09.00am, 14.00 pm and 19.00 pm). Oral body temperatures of the subjects were measured prior to each test. As a conclusion, when visual simple and multiple reaction time values were analyzed, the best results were at 09.00. For flexibility and jumping parameters, a gradual increase was seen between morning and evening with an increase in body temperature. In addition, it can be said that in studies conducted on athletes, measurement hours should be chosen carefully based on the parameters to be measured in order to get more correct and reliable results.

INTRODUCTION

Time dependent cyclic changes in human beings have been observed for centuries. There is an order and rhythm in the universe, including the earth, which is a part of the universe, while there is a biological rhythm in the living beings on earth (Waterhouse 1999).

Circadian rhythm is the rhythm that is under the control of the suprachiasmatic nucleus (SCN) which is located in the front hypothalamus of our brain. Circadian rhythm is also called the biological clock. This clock helps the organism in adapting to the environment and is responsible for adjusting the sleep-wake cycle (Dunlap 1999; Hastings 2007; Sancar 2010). A great number of performance indicators follow the circadian changes in the body temperature (Reilly and Bambaeichi 2003). Basically, body temperature is considered as the "basic variable" of circadian rhythm and it is used as the determiner of circadian rhythm (Waterhouse 2005).

The association of circadian rhythm with many physiological variables in sportive perfromance has attracted the attention of researchers. It has also been studied extensively. Nishimura et al. (2014) suggest that AT (anaerobic threshold) is reached at a lower intensity in the morning than in the afternoon, and that relative burden, as indicated by HR (heart rate) and SBP (systolic blood pressure), is greater in the morning than in the afternoon. Studies have found circadian changes in aerobic power (Hill et al.1992; Hill 1996) heartbeat rate (Reilly and Brooks 1986; Akkurt et al.1996; Gunes et al.1998), blood pressure (Gunes et al.1998) and central body temperature (Reilly and Brooks 1986). In addition, it has also been stated that age, type and severity of exercise, jet-lag effect, insomnia and training time affect the aforementioned daily changes (Reilly et al. 2000).

Despite the debates on the significance of endogenous and exogenous mechanisms on circadian rhythms in sports performance; if sportive performance differs with respect to the time of theday under normal daily conditions, it directly affectsthe athlete. This effect makes understanding circadian change in sportive performance an important factor for athletes and trainers in terms of practice (Cappaert 1999) and it can have important effects on both short term and long term success of an athlete or a team. Within this context, the purpose of our study wasto assess performance at different times of the day so that we canfind out the period of time that can be more efficient for athletes and trainers.

MATERIAL AND METHODS

Samples

A total of 25 male students (athletes) studying at Ondokuz Mayis University Faculty of Yasar Dogu Sports Sciences participated in this study voluntarily. The average age of the students was 23.00±2.44 years, their average weight was 70.68±8.41 kg, while their average height was 174.36±5.00 cm. The study was conducted in line with the 2013/509 decision of the ethical board of Ondokuz Mayis University Faculty of Medicine.

Study Method

The subjects were informed about the device and the measurements to be used. The measurements were made in the laboratory of Ondokuz Mayis University Faculty of Yasar Dogu Sports Sciences. The test day was carefully selected to be a day of rest for all the subjects. The measurements were made at 3 different hours during the day, as 09.00, 14.00 and 19.00. These measurements at different times of the day were made every other day. The subjects were grouped in three groups of 8-9 students randomly and measurements were made at different hours and days as shown in Table 1.

Body Temperature

Body temperatures of the subjects were measured with no touch forehead infrared thermometer. The subjects were made to sit on chairs. The person who made the measurements sat right opposite to the subject. The subjects were checked for sweat or hair on the forehead. The measurement was made at a distance of 5 cm between the thermometer and the forehead.

Reaction Time Measure

Reaction time measurements were made with MOART Lafayette reaction measurement device. The measurements were made in two ways known as simple and multiple visual reaction measurements.

Visual simple reaction time measurement was made ten times, of five consecutive times for the right hand and five consecutive times for the left hand. The best and the worst values were excluded from these results and the arithmetic mean of the remaining three values was recorded as thevisual simple reaction time.

Twelve stimuli were given to determine the multiple reaction time of the subjects. The best and the worst values were excluded from the results and the arithmetic means of the remaining eight values were recorded as multiple reaction time of the subjects. Measurements were taken with the weight of the subjects' fingers on the related buttons.

Sit and Reach Test

The subjects' flexibility measurements were made with the sit and reach test. The test was repeated twice and the highest value was recorded as flexibility measurement value.

Static Jump

Static jump test was made by using the Newtest Powertimer 300 equipment. The subjects were made to get on anautomatic calibrated, wide and precise measurement surface of 84x95 cm rectangular mat. They kept their legs bent from their knees with their hands on their waist and they were asked to jump when they were ready. This move was repeated for five times and the best value was recorded as the vertical jump value.

Static and Dynamic Balance Measures

CSMI make Prokin Tecno Body isokinetic balance measurement device was used for static and dynamic balance measurements.

Static test was made on a field platform, on both feet and one foot (right and left) standing position with eyes open and closed. In both legs test, the standing position was determined with feet open as wide as the shoulder and the standing position of the feet equal to the originating point by taking the lines on the x and y axis of the platform as references. In one foot test, it was determined as one foot coming to the middle of the originating point. The subject was asked to look at a fixed point in front of him and the test commenced after the balance was found. During the test which lasted for 30 seconds, the

Table 1: Subject grouping and measurement hours

Subjects	*N*	*Measurements and hours*		
		09.00	*14.00*	*19.00*
1. group	8	1. measurement	3. measurement	2. measurement
2. group	8	2. measurement	1. measurement	3. measurement
3. group	9	3. measurement	2. measurement	1. measurement

subject was asked to keep his position and the subject followed the position from the screen. The test started by pressing the start button on the computer keyboard and at the end of the test, it was ended automatically by the computer. As the balance score increased, the subject's static balance was considered to be bad and as the score decreased, the balance static balance was considered to be good.

Dynamic test was realized when both feet are in standing position. The standing position was the same as the static balance test. The test was completed by making five clockwise rounds in the platform in sixty seconds while following the circular route on the screen. For the subjects who could not complete the test within the specified time, their performance up to that point was recorded as the test result. As the balance score increased, the subject's dynamic balance was considered to be bad,but as the score decreased, it was considered to be good.

Statistical Analysis

The statistical analysis of the data was made using SPSS 21 package program. Arithmetic means and standard deviations of the data were calculatedas well. Repetitive analysis test and Bonferroni correction paired comparison test were used to find out whether the circadian rhythm was effective on the measured parameters. Statistical significance was ($p<0.05$) and ($p<0.01$).

RESULTS

When the subjects' body temperatures were analyzed based on their circadian rhythm, it was found that the body temperatures measured at 19.00 were significantly higher than those measured at 09.00 and 14.00 ($p<0.01$).

When the subjects' reaction times were analyzed based on their circadian rhythm, it was found that the reaction times measured at 9.00 were significantly higher than those measured at 14.00 and 19.00 ($p<0.01$, $p<0.05$).

When the subjects' flexibility levels were analyzed based on their circadian rhythm, it was found that the flexibility levels measured at 19.00 were significantly higher than those measured at 09.00 and 14.00 ($p<0.01$) (Table 2).

When the subjects' static jump values were analyzed based on their circadian rhythm, it was found that the period of flight time and jumping height values measured at 19.00 were significantly higher than those measured at 09.00 and 14.00 ($p<0.01$, $p<0.05$) (Table 3).

Mean force variance value (AFV), one of the sub parameters of dynamic balance measurements that were analyzed based on the circadian rhythm, was significantly higher at 09.00 when compared with 19.00 and 14.00 ($p<0.01$). However, no significant difference was found between other dynamic balance measurements which were

Table 2: The subjects' body temperature, reaction time and flexibility test measurements based on the circadian rhythm

Variables	*Hours*	*Mean*	*SS*	*F*	*P*
Body Temperature (°C)	09.00 (1)	36.28	0.30	47.217	1,2<3**
	14.00 (2)	36.43	0.37		
	19.00 (3)	36.85	0.31		
Simple Reaction Time(ms) (Right Hand)	09.00 (1)	155.20	19.73	66.460	1<2,3**
	14.00 (2)	179.16	19.84		
	19.00 (3)	195.04	14.57		
Simple Reaction Time(ms) (Left Hand)	09.00 (1)	161.64	21.42	42.192	1<2,3**2<3*
	14.00 (2)	181.12	30.44		
	19.00 (3)	204.04	26.83		
Choice Reaction Time(ms)	09.00 (1)	402.80	50.5	20.833	1<2*1<3**
	14.00 (2)	447.80	49.0		
	19.00 (3)	471.14	65.79		
Flexibility (cm)	09.00 (1)	25.54	3.50	5767	3>1,2**
	14.00 (2)	27.50	3.59		
	19.00 (3)	29.06	3.39		

** $p<0.01$ * $p<0.05$

Table 3: The subjects' static jump test measurements based on the circadian rhythm

Variables	Hours	Mean	SS	F	P
Flight Time(ms)	09.00 (1)	531.68	29.83	11.382	1<2* 1<3**
	14.00 (2)	544.12	31.77		
	19.00 (3)	547.28	29.79		
Jump Height (cm)	09.00 (1)	34.58	3.84	15.070	1<2,3**
	14.00 (2)	36.27	4.24		
	19.00 (3)	36.88	3.95		
Jump Power	09.00 (1)	3216.48	352.16	2.456	-
	14.00 (2)	3349.52	463.28		
	19.00 (3)	3322.80	429.80		

**$p<0.01$ *$p<0.05$

analyzed, based on circadian rhythm ($p>0.05$) (Table 4).

In Table 5, static balance tests based on circadian rhythm with both feet, eyes open and eyes closed showed that circadian rhythm did not change the balance levels of the subjects significantly ($p>0.05$)

In Table 6, static balance tests based on circadian rhythm with right foot, eyes open and eyes closed showed that circadian rhythm did not change the balance levels of the subjects significantly ($p>0.05$).

In Table 7, Static balance tests based on circadian rhythm with left foot, eyes open and eyes

Table 4: The subjects' dynamic balance measurements based on the circadian rhythm

Variables	Hours	Mean	SS	F	P
ATE (%)	09.00 (1)	26.96	11.35	0.427	-
	14.00 (2)	25.60	9.17		
	19.00 (3)	24.76	13.56		
AFV(kg)	09.00 (1)	2.43	0.67	5.316	1>2**
	14.00 (2)	2.11	0.55		
	19.00 (3)	2.19	0.55		
Stability Index	09.00 (1)	0.82	0.42	2.016	-
	14.00 (2)	0.72	0.48		
	19.00 (3)	1.32	1.91		
Delay (%)	09.00 (1)	0.760	1.05	0.677	-
	14.00 (2)	1.08	1.38		
	19.00 (3)	0.920	1.15		

**$p<0.01$

Table 5: The subjects' both feet static balance measurements based on the circadian rhythm

Variables	Hours	Open eyes both feet			Closed eyes both feet		
		Mean	SS	F	Mean	SS	F
Average C.o.P.X (mm)	09.00 (1)	0.32	0.94	2.578	0.12	4.06	0.388
	14.00 (2)	0.00	0.86		-0.04	3.12	
	19.00 (3)	-0.12	0.83		-0.68	4.64	
Average C.o.P.Y (mm)	09.00 (1)	-1.08	2.17	0.306	-2.44	4.29	0.594
	14.00 (2)	-1.32	1.28		-1.72	5.00	
	19.00 (3)	-1.40	1.52		-1.20	4.25	
*Elipse Area (mm*2)*	09.00 (1)	359.12	166.97	0.793	514.36	247.00	1.615
	14.00 (2)	344.92	199.12		433.88	224.20	
	19.00 (3)	397.36	185.85		509.16	249.94	
Perimeter (mm)	09.00 (1)	442.08	109.91	1.964	558.92	123.38	1.673
	14.00 (2)	430.72	106.60		506.88	148.13	
	19.00 (3)	478.60	97.40		516.80	139.86	

Table 6: The subjects' right foot static balance measurements based on the circadian rhythm

Variables	*Hours*	*Open eyes both feet*			*Closed eyes both feet*		
		Mean	*SS*	*F*	*Mean*	*SS*	*F*
Average C.o.P.X (mm)	09.00 (1)	3.48	3.13	0.987	2.88	5.18	0.424
	14.00 (2)	3.24	3.91		2.04	5.38	
	19.00 (3)	2.52	3.79		2.20	4.18	
Average C.o.P.Y (mm)	09.00 (1)	-0.68	2.52	0.153	-0.84	6.03	0.706
	14.00 (2)	-1.00	2.62		-1.76	4.79	
	19.00 (3)	-0.96	2.33		-0.20	4.91	
*Elipse Area (mm*2)*	09.00 (1)	557.40	231.35	0.448	2971.84	1195.23	0.894
	14.00 (2)	507.16	253.45		2905.36	1238.85	
	19.00 (3)	552.28	307.31		2606.56	1225.01	
Perimeter (mm)	09.00 (1)	1125.36	259.65	1.007	1994.72	453.42	1.129
	14.00 (2)	1156.64	296.15		2052.80	444.57	
	19.00 (3)	1091.32	257.85		2155.52	562.08	

Table 7: The subjects' left foot static balance measurements based on the circadian rhythm

Variables	*Hours*	*Open eyes both feet*			*Closed eyes both feet*		
		Mean	*SS*	*F*	*Mean*	*SS*	*F*
AAverage C.o.P.X (mm)	09.00 (1)	-1.24	2.18	0.800	-2.08	7.94	0.255
	14.00 (2)	-1.84	2.40		-2.52	5.93	
	19.00 (3)	-1.12	2.57		-1.24	6.11	
Average C.o.P.Y (mm)	09.00 (1)	-0.64	2.65	1.179	-5.04	13.10	0.010
	14.00 (2)	-1.44	2.45		-4.76	11,11	
	19.00 (3)	-1.28	2.07		-4.64	10.20	
*Elipse Area (mm*2)*	09.00 (1)	634.72	210.65	1.110	2430.28	75235	0.137
	14.00 (2)	819.60	787.00		2555.28	937.20	
	19.00 (3)	659.00	231.76		2475.12	931.80	
Perimeter (mm)	09.00 (1)	1032.40	266.51	2.645	1823.84	333.38	0.755
	14.00 (2)	1152.00	277.63		1931.04	440.63	
	19.00 (3)	1153.28	276.59		1817.28	481.91	

closed showed that circadian rhythm did not change the balance levels of the subjects significantly (p>0.05).

DISCUSSION

The purpose of this study was to analyze the circadian changes in some physical performance measurements.

In the study, when the subjects' body temperatures at different times were measured, it was found that the body temperature increased gradually from morning to evening (09.00-36.28±0.30°C, 14.00-36.43±0.37°C, 19.00-36.85±0.31°C). The body temperature measured at 19.00 was found to be statistically higher than the body temperature measured at 09.00 and 14.00. There are a great number of studies in literature that support this finding. Reilly and Brooks (1990) and Reilly (1990), stated that the body temperature increased in the evening hours when compared with the morning hours and the body temperature reached its highest level between the hours of 17.30 - 20.30.

The adjustment of many functions of the organism occurs based on the sleep-wake cycle. With sleep, heart beat rate and respiration slow down and thus, the body temperature decreases. Circadian changes in body temperature have frequently been reported. Willke et al. (2002), found that body temperature changed during the day and in circadian rhythm, in such a way that the body temperature was at its lowest in the morning and at its highest in the afternoon; and in addition, the difference between the body temperatures of the morning and the afternoon was 0.5°C-1°Cin the circadian rhythm.

Venugopal et al. (2010) analyzed the effect of circadian rhythm on different parameters such as body temperature, respiratory rate, adding up and counting. With this purpose, measurements were made at four different times of the day (07.00, 11.00, 15.00 and 19.00). They found that the body temperature and the respiratory rate accordingly reached their highest levels in the early hours of the evening. As a result of the study, they stated that there were two basic rhythms which are related to exercise and sport performance. The first of these was body temperature while the second one was sleep-wake cycle.

Fourteen university students voluntarily participated in Kin-Isler's (2005) study which was aimed at analyzing the circadian changes in anaerobic performance by the active jump test and by the Wingate anaerobic power tests in three different days and periods (09.00, 13.00 and 17.00). While a significant difference was found in oral body temperature, maximal strength, maximal anaerobic power and average power values; no significant circadian change was found in bodyweight and rested heartbeat rate within the measured time intervals.

Hill and Smith (1991) and Melhim (1993), found significant differences in oral body temperature in four different periods of time. The highest body temperature was reached at 19.00 while the lowest body temperature was reached between 03.00-09.00 a.m. Similarly, Hillet al. (1989), found that the highest body temperatures were at evening hours and the lowest body temperatures were at morning hours. Sekir et al. (2002), found that of the oral body temperatures measured at three different periods of time, the highest temperatures were at 19.00-14.00-9.00, respectively. Body temperature results in this study were found to be in parallel with the literature.

When the subjects' right and left hand visual simple reaction times based on circadian rhythm were analyzed, the reaction times measured at 9.00 were found to be statistically better than those measured at 14.00 and19.00. In addition, when the subjects' multiple reaction times based on circadian rhythm were analyzed, the reaction times measured at 9.00 were found to be statistically better than those measured at 14.00 and 19.00. There are a great number of studies that support the findings of our study.

Visual simple reaction time which was found to have changes based on circadian rhythm was found to reach its maximum levels at 10.00 and then decrease at about 15.00 according to the results of Hildebrandt's (1985) study, which is similar to a great number of studies. Another study found that audio and visual reaction times were at the lowest at 18.00 (Charles et al. 1985). However, there are also findings which are different from ours. Reilly and Garrett (1998), found that audio and visual simple reaction times were at their best in the early hours of the evening just like the body temperature which reached its highest level. A great number of studies have mentioned circadian variety in reaction time. The reason for this difference may be the groups and the differences in study method.

Since the level of noradrenaline hormone is higher at morning hours and since it increases awakeness and attention in limbic system, it may be useful in terms of reaction studies (Charles et al.1985).

Further, in the study, when the subjects' flexibility values based on circadian rhythm were analyzed, the values measured at 19.00 were found to be statistically higher than those measured at 09.00 and 14.00. Drust et al. (2012), also found out that flexibility reached best values in the early hours of the evening. Similarly, Gifford (1987) recorded that flexibility changed for better later in the day. However, it has been reported that flexibility can be at its best between 12.00 and 24.00, but there may be big interpersonal differences (Edwards and Atkinson 1998). According to the results of the study, it has been found that circadian rhythm causes flexibility to change based on the time of the day.

In Reilly et al.'s study (2007) which was conducted with 8 male football players playing in a professional team and 8 male football players playing in a university team, body temperature, gripping force, reaction time, flexibility, wall-volley and football specific skills test values were compared at different days and hours (8.00, 12.00, 16.00, 20.00). The best values were reached at 16.00 for football specific skill tests, at 20.00 for wall-volley test, at the early hours of the evening for body temperature (16.00) and 16.00-20.00 for flexibility. As a result, they found that the hours when footballers reached their best football-specific performances were 16.00-20.00 and not only football specific skills but also performance test measurements reached their peak level at the same time interval.

Static jump values which were measured based on circadian rhythm were also analyzed in our study. The best jumping height and jumping period were found to be at 14.00 and 19.00 and these values were found to be statistically higher than those of 09.00. When the subjects' static jumping strength based on circadian rhythm were analyzed, best measurements were reached at 14.00, although, no statistically significant differences were found. One study that was in parallel with our study assessed the effect of circadian rhythm in anaerobic performance attained by active jumping and Wan T tests (Kin-Isler 2005).

When the subjects' dynamic balance measurements based on circadian rhythm were analyzed, no significant difference was found in average track error (ATE) and stability index measurements. The subjects' average force variance (AFV) based on dynamic balance measurements was significantly higher at 9.00 when compared with the measurements at 19.00 and 14.00. Although, stability indicator values did not show a significant difference based on circadian rhythm, the fact that the values were close to zero at 09.00 and 14.00 shows that the balance problem in these hours is less. Colquhoun (1972), stated that balance skill is better at morning hours. Thus, it can be said that this finding is in parallel with the findings of our study.

According to the static balance test based on circadian rhythm, circadian rhythm was not found to cause a statistically significant difference on the balance levels of the subjects. In literature review, no study which compared the balance values at different hours of the daywas found. Thus, our findings were not compared with other studies.

CONCLUSION

To conclude, when visual simple and multiple reaction time values were analyzed, the best results were at 09.00. Within this context, these hours can be said to be suitable for moves that require awakeness and attention. In flexibility and jumping parameters, a gradual increase was seen from morning to evening with the increase in body temperature. Within this context, the best performance values can be attained by adjusting the trainings and competitions to the hours when the body temperature is at its highest to get the best performance from trainings and competitions.

RECOMMENDATIONS

In studies conducted on athletes, measurement hours should be chosen carefully based on the parameters to be measured to get more correct and reliable results. Further, the importance of specifying the hour of measurements in scientific studies has been proven with this study.

REFERENCES

Akkurt S, Gur H, Kucukoglu S 1996. Diurnal observations in performance test results. *Turkish Journal of Sports Medicine*, 31(3): 93-105.

Cappaert TA 1999. Time of day effect on athletic performance: An update. *J Strength Cond Res*, 13(4): 412–421.

Charles MW, Charles WD, Daniel CH 1985. Circadian rhythms and athletic performance. *Med Sci Sports Exerc*, 17(5): 498-516.

Colquhoun WP, Hockey GR 1972. Diurnal variation in human performance. In:WP Colquhoun (Ed.): *A Review: Aspects of Human Efficiency. Diurnal Rhythm and Loss of Sleep*. London: English Universities Press, pp. 1-23.

Drust B, Ahmed Q, Roky R 2012. Circadian variation and soccer performance: Implications for training and match-play during Ramadan. *J Sports Sci*, 30(1): 43–52.

Dunlap JC 1999. Molecular bases for circadian clocks. *Cell*, 96(2): 271-290.

Edwards BJ, Atkinson G 1998. Effect of time of day on flexibility in morning and evening chronotypes. *Journal of Sports Sciences*, 16(1): 45–46.

Gifford LS 1987. Circadian variation in human flexibility and grip strength. *Aust J Physiotherapy*, 33: 3-9.

Gunes H, Arslan A, Erdal S 1998. Investigating the circadian rhytm of recovery pulse sum.*Hacettepe J of Sport Sciences*, 9(1): 15-29.

Hastings M, O'Neill JS, Maywood ES 2007. Circadian clocks: Regulators of endocrine and metabolic rhythms. *J Endo-crinol*, 195(2): 187-198.

Hildebrandt G, Pöllmann L1985. Chronobiologische aspekte der zahnarztlichen tatigkeit In: M Heners u.a. (hrsg): *Arneit Swissenchaft in der Zahnheilkunde.* Berlin: Methoden und Ergebnisse, pp.119-131.

Hill DW1996. Effect of time of day on aerobic power in exhaustive high-intensity exercise. *J Sports Med Phys Fitness*, 36(3): 155-160.

Hill DW, Smith JC 1991. Circadian rhythm in anaerobic power and capacity. *Can J Sport Sci*, 16(1): 30-32.

Hill DW, Borden DO, Darnaby KM, Hendricks DN, Hill CM 1992. Effect of time of day on aerobic and anaerobic responses to high-intensity exercise. *Can J Sport Sci*, 17(4): 316-319.

Hill DW, Curreton KJ, Collins MA, Grisham SC 1989. Effect of the circadian rhythm in body temapature on oxygen uptake. *J Sports Med Phys Fitness*, 28: 213-219.

Kin-Isler A 2005. Evaluation of circadian rhthyms in anaerobic performance. *Hacettepe J of Sport Sciences*, 16(4): 174-184.

Melhim AF 1993. Investigation of circadian rhythms in peak power and mean power of female physical education students. *Int J Sports Med*, 14(6): 303-306.

Nishimura K, Nagasaki K, Yamaguchi H, Yoshioka A, Nosa Y, Onodera S, Takamoto N 2014. Circadian

variations in anaerobic treshold. *Kinesiology,* 46(2): 164-170.
Reilly T 1990. Human circadian rhythms and exercise. *Crit Rev Biomed Eng,* 18(3): 165-180.
Reilly T, Atkinson G, Edwards B, Waterhouse J, Farrelly K, Fairhurst E 2007. Diurnal variation in temperature, mental and physical performance and tasks specifically related to football (soccer). *Chronobiol In,* 24(3): 507–519.
Reilly T, Atkinson G, Waterhouse J 2000. Chronobiology and physical performance. *Exercise and Sport Science, Philadelphia,* 351-372.
Reilly T, Bambaeichi E 2003. Methodological issues in studies of rhythms in human performance. *Biol Rhythm Res,* 34(4): 321-336.
Reilly T, Brooks GA 1986. Exercise and the circadian variation in body temperature measures. *Int J Sports Med,* 7(6): 358-362.
Reilly T, Brooks GA 1990. Selective persistence of circadian rhythms in physiological responses to exercise. *Chronobiol Int,* 7: 59-67.
Reilly T, Garrett R 1998. Investigation of diurnal variation in sustained exercise performance. *Ergonomics,* 41: 1085-1094.
Reilly T 1990. Human circadian rhythms and exercise. *Crit Rev Biomed Eng,* 18(3): 165-180.
Sancar A et al. 2010. Circadian clock control of the cellular response to DNA damage. *FEBS Lett,* 584(12): 2618-2625.
Sekir U, Ozyener F, Gur H 2002. Effect of time of day on the relationship between lactate and ventilatory thresholds: A brief report. *J Sport Sci Med,* 1(4): 136-140.
Venugopal R, Gupta O, Patel H 2010. Temporal pattern of circadian rhythm in sportsmen. *Journal of Exercise Science and Physiotherapy,* 6(1): 1-6.
Waterhouse J 1999. Introduction to chronobiology. In: N Abacioglu, H Zengil (Eds.): *Fundamentals of Chronobiology and Chronotherapy.* Ankara: Palme Publishing, pp. 1-13.
Waterhouse J, Drust B, Weinert D, Edwards B, Gregson W, Atkinson G, Kao S, Aizawa S, Reilly T 2005. The circadian rhythm of core temperature: Origin and some implications for exercise performance. *Chronobiol Int,* 22(2): 207-225.
Willke Topcu A, Soyletir G, Doganay M 2002. Infectious diseases and microbiology: S.O. Fever and fever of unknown origin. *Nobel Medicine Bookshops,* 503-528.