INFLUENCE OF CIRCADIAN RHYTHM ON SELECTED PHYSIOLOGICAL VARIABLES AND SWIMMING PERFORMANCE OF SCHOOL BOYS

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ABSTRACT

When the circadian rhythms of physical physiological and psychological factors determining sports performance are closely in 'sync' that would be the zone of peak performance for a particular individual is well documented. The purpose of the study was to find out the influence of Circadian Rhythm on selected physiological variables and swimming performance. To achieve the purpose of the study, fifteen male health students of age group 16 to 18 years, were selected as subjects and physiological variables such as body temperature, resting heart rate, anaerobic power, aerobic power and swimming performance were selected as dependent variables. Circadian rhythm was selected as another categorical variable, which was calculated from six different times of the day 02.00, 06.00, 10.00, 14.00, 18.00 and 22.00 hours. The standard tests for the selected dependent variables were administered and the collected data were statistically treated with one way analysis of variance and Scheffe's post hoc test to find out the difference. Cosinor analysis was used to find out the existence of significant circadian rhythm. The results showed that body temperature, resting heart rate, anaerobic power, aerobic power and swimming performance showed significant difference in different times of the day and circadian rhythm was significant in body temperature and aerobic power.

Key words: *Circadian Rhythm, Anaerobic power, Aerobic power, Body temperature, Resting heart rate, swimming performance.*

INTRODUCTION

Performance of man in sport or any other field depends on his movement oriented behavior and all these actions have their roots in biological phenomena. This biological phenomenon is the foremost, which fluctuates periodically and so does the performance. Athletic performance that occurs several hours before or after the circadian peak 'window' will potentially subjected to less than optimal performance. The ties between body temperature and motor performance suggest that the exercise is best performed at the crest time of core temperature. The optimal core and muscle temperature for exercise is about 38.3^{o}C and 40^{o}C respectively. The resting temperature is closet to these values in the evening. Faster performance at the crest time of body temperature may be linked with local temperature in active muscles and other soft tissues. A circadian variation is reported for joint stiffness. The increased resistance to motion as the joint cools should impair flexibility as well as speed of movement. A variation in trunk flexibility was found the trough occurring in the morning and peak in the afternoon. Many human performance measures tend to follow closely the circadian rhythm in body temperature.

Once we have learned at what hour our body temperature reaches its highest and lowest points, we are ready to apply the principles of 'chronobiology' to improve both our health and our performance. It is proved that we do our best of the physical work when our body rhythms are at their peak. Planning to work the hardest when our core temperature is at its peak will be fruitful. Knowledge of our body rhythms also helps in the recovery phase of training.

If we trace the world records in athletics for the past 60 years, most of them are set in the late afternoon or evening. For example, World record performance in distance races between 800 mts to 5000 mts too place between 19.00 hours and 23.00 hours, that is when the ambient temperature and body temperature are at their peak. The fact that freely chosen level of exervise is highest at the time the body temperature rhythm reaches a peak has important implications for training as well as for certain competitive sports. As far as explosive type of activities are concerned world records in men's shot put and women's javelin were set in the morning. Rhythms have been identified sensory motor (reaction time) psychomotor (hand-eye co-ordination), sensory perceptual, cognitive, and psychological functions. Fencers had their best scores, as far as they are related to speed and skill, around noon. Explosive actions with substantial neuromotor components may be linked more closely to the arousal rhythm than to that of body temperature and perhaps reach a peak earlier in the day.

Sports requiring fast explosive efforts tend to peak earlier and may be related to sleep-wake cycle (clock) rather than to body temperature. Consequently, practices where skills have to be acquired should be conducted early in the day or around mid-day, but more severe training drills and 'pressure training' are best timed for later in the day.

It is accepted that sports performances are determined by many variables and there may be multiple performance rhythms. This can be further examined by looking at existence of rhythms in components of sports performance.

The scope of this study is to analyse the circadian rhythm on selected physiological variables, which have the main contribution of sports performance. Each variable has its own peak time and trough time. But if the peak times of all these selected variables would be predicted and if their peak times are closer together then that time would be better time for

peak performance of that particular individual or group.

Circadian rhythm of many variables has been established in previous works. Not much works have been carried out to find to what extent these rhythm varies in higher secondary school boys. There is no notable research works in this area conducted to for swimmers and their performances. If we have the knowledge of peak performance of an individual then we can go accordingly to plan training methods and strategies to improve further and exhibit highest performance in the competition.

MATERIALS AND METHODS

Selection of Variables

Reilly (1987) states that stability is a rare feature in nature, as most of living things exhibit fluctuations in their states. Their changes may be regular, recurring on a cyclical and predictable basis. Focus of this study is on circadian variation or rhythmic change in human being during each solar day.

In the present study, fifteen male swimmers who are also students of Arulmihu Senthil Andavar Government Boys Higher Secondary School, Tiruchendur were selected as one categorical variable. They were in good state fitness and regularly took part in swimming. They are all aged between 16 to 18 years. Circadian rhythms usually form sinusoid within a period about 24 hours. So six different times of the day 02.00, 06.00, 10.00, 14.00, 18.00, 22.00 hours were selected as another categorical variables.

To serve the purpose of the study the following dependent variables were selected for this study such as body temperature, resting heat rate, anaerobic power, aerobic power and swimming performance. Body temperature and resting heart rate were measured by bio monitor, anaerobic power was estimated by Maragaria Kalamen stair run test, Aerobic power was calculated by Queen's college step test and Swimming performance was measured by 50 meters freestyle swim.

Collection of Data

Atkinson and Reilly (1996) also reported in their study that human performance cannot be monitored continuously in order to describe circadian rhythmicity. To control serial fatigue effects and to minimize disturbances in sleep, tests were conducted in such an order, from less strain tests to more strain tests.

Time schedule for collection of data

Reilly (1994) revealed that the most well known type of rhythm in man is the body temperature which often rises to its highest value towards the late afternoon and reaches a low point early in the morning and it modifies many physiological variables. Body temperature and sleep wake cycle are called endogenous rhythms since they persist even under the constant environmental, conditions or circumstances devoid of time cues. So, based on body temperature curve the tests were conducted at six times a day with every four hours in between the time points, ie., 02.00, 06.00, 10.00 14.00, 18.00 and 22.00 hours. The order of test administration was balanced for times of day and the minimum time between test sessions was eight hours as prescribed by Atkinson, et al (1993) and Reilly (1992). i.e., on first day 02.00, 10.00 and 18.00 hours and on second day 06.00, 14.00 and 22.00 hours. Subjects' diet and activity prior to the exercise tests were controlled. No strenuous exercises were permitted within 24 hours of testing. The last meal prior to any test session was taken at least three hours before the exercise. The subjects were restricted from consuming beverages, smoking and excess of caffeine during the testing times. They were permitted to sleep before the 06.00 hours test but stayed awake for the test at 02.00 hours.

Order of Testing

The selected dependent variables are tested by administering the standardized tests starting from less strenuous to strenuous tests. i.e., Body Temperature, Resting Heart Rate, Anaerobic Power, Aerobic Power and finally Swimming Performance.

Experimental and Design and Statistical Procedure

Static group factorial design consisted of circadian variation measured at six different times of the day (02.00, 06.00, 10.00 14.00, 18.00 and 22.00 hours). One way analysis of variance was used to find out the influence of each of the factors independently and also their combined influence on each of the selected variables. Scheffe's post hoc test was applied to find out the significant difference between each cell and .05 level of significance was fixed to test the hypothesis.

Circadian rhythmicity was explored using the best fitting curve procedure (Nelson et al., 1979) Gupta and Pati, (1992). The mean value from each cell being subjected to cosinor analysis to find out the parameters of circadian rhythm, the percentage rhythm with probability level, the mesor value, the amplitude and acrophase for each variable of higher secondary school boys. Circadian rhythm was considered statistically significant when $p \leq .05$.

RESULTS AND DISCUSSIONS

The collected data for the selected variables from administering tests were statistically analysed and the results of Mean and standard deviation, one way analysis of variance, Scheffe's post hoc test and cosinor analysis are given below. Mean and standard deviation of selected variables are presented in Table I.

Table-I: **Summary of Mean and Standard Deviation of Selected Variables of Higher Secondary School Boys At Different Times of the Day**

Variables	Times of the day						Mx
	02.00	06.00	10.00	14.00	18.00	22.00	
Body Temperature	95.667 ±0.419	96.267 ±0.918	96.613 ±0.664	96.933 ±0.494	97.253 ±0.416	96.833 ±0.422	96.594
Resting Heart Rate	67.000 ± 2.268	72.000 ±4.884	72.867 ±2.800	75.000 ±4.036	78.000 ±3.645	74.000 ±3.443	73.144
Anaerobic Power	72.553 ±3.718	77.513 ±4.102	78.727 ±3.392	81.420 ±2.590	84.593 ±2.940	81.400 ±2.493	79.368
Aerobic Power	46.173 ±3.458	48.508 ±2.720	51.555 ±2.414	53.552 ±2.579	55.485 ±2.885	50.297 ±3.029	50.928
Swimming Performance	32.001 ±0.934	31.821 ±0.795	31.355 ±0.975	30.907 ±0.940	30.876 ±0.928	30.599 ±1.001	31.260

The data of selected variables of higher secondary school boys were analyzed by Analysis of variance and the results obtained are presented in Table II.

Table-II: **Summary of ANOVA on Selected Variables of Higher Secondary School Boys at Different Time of the Day**

Variables	**Source of Variance**	**Sum of Squares**	**df**	**Mean Square**	**'F' value**	**Table Value**
Body Temperature	Between Groups	23.619	5	4.724	13.803*	2.324
	Within Groups	28.748	84	0.342		
	Total	52.367	89			
Resting Heart Rate	Between Groups	1003.389	5	200.678	15.384*	2.324
	Within Groups	1095.733	84	13.044		
	Total	2099.122	89			
Anaerobic Power	Between Groups	1289.019	5	257.804	24.278*	2.324
	Within Groups	891.977	84	10.619		
	Total	2180.997	89			
Aerobic Power	Between Groups	853.630	5	170.726	20.763*	2.324
	Within Groups	690.693	84	8.223		
	Total	1544.323	89			
Swimming Performance	Between Groups	23.736	5	4.747	5.473*	2.324
	Within Groups	72.868	84	0.867		
	Total	96.604	89			

One way analysis of variance shows that the obtained 'F' value for all the selected variables (body temperature – 13.803, resting heart rate – 15.384, anaerobic power – 24.278, aerobic power – 20.763 and swimming performance – 5.473) are greater than the table value (2.324). This indicates that there is a significant difference in selected variables of higher secondary school boys at different times of the day.

To explore which of the paired means have the significant difference in swimming performance, Scheffe's post hoc test was applied.

The differences in selected variables between different times of day are presented in Table III.

Table-III: **Summary of Scheffe's Test for Difference between the Paired Means of Swimming Performance of Higher Secondary School Boys at Six Different Times of the Day**

	2 am	6am	10 am	2 pm	6 pm	10 pm	MD	CI	Result
Body Temperature	95.667		96.613				0.946	0.728	Sig
	95.667			96.933			1.266	0.728	Sig
	95.667				97.253		1.586	0.728	Sig
	95.667					96.833	1.166	0.728	Sig
		96.267			97.253		0.986	0.728	Sig
Resting Heart Rate	67.000	72.000					5.000	4.496	Sig
	67.000		72.867				5.867	4.496	Sig
	67.000			75.000			8.000	4.496	Sig
	67.000				78.000		11.000	4.496	Sig
	67.000					74.000	7.000	4.496	Sig
		72.000			78.000		6.000	4.496	Sig
Anaerobic Power	72.553	77.513					4.960	4.056	Sig
	72.553		78.727				6.173	4.056	Sig
	72.553			81.420			8.867	4.056	Sig
	72.553				84.593		12.040	4.056	Sig
	72.553					81.400	8.847	4.056	Sig
		77.513			84.593		7.080	4.056	Sig
			78.727		84.593		5.867	4.056	Sig
Aerobic Power	46.173		51.555				5.382	3.569	Sig
	46.173			53.552			7.379	3.569	Sig
	46.173				55.485		9.312	3.569	Sig
	46.173					50.297	4.125	3.569	Sig
		48.508		53.552			5.044	3.569	Sig
		48.508			55.485		6.977	3.569	Sig
			51.555		55.485		3.930	3.569	Sig
					55.485	50.297	5.187	3.569	Sig
Swimming Performance	32.001					30.599	1.402	1.159	Sig
		31.821				30.599	1.223	1.159	Sig

The results of Scheffe's post hoc test clearly indicate that selected variables differ as the time of the day varies. The difference in body temperature found to be significant in 5 paired means, the difference in resting heart rate found to be significant in 6 paired means, the difference in anaerobic power found to be significant in 7 paired means, the difference in aerobic power found to be significant in 8 paired means and the difference in swimming performance found to be significant in 2 paired means. Circadian Rhythmicity of selected variables and their parameters were explored using the best fitting curve procedure. The mean value from the data being subjected to cosinor analysis and the results are presented in table IV.

Table-IV: **Cosinor Analysis of Circadian Rhythmicity of Selected Variables of Higher Secondary School Boys**

Variables	Percent Rhythm	Proba- bility Level	Mesor±S.E.	Acro- phase± S.E.	Ampli- tude± S.E.
Body Temp	90.365*	0.03	96.594± 0.092	17.26 Hours ±1 h 12 m.	0.688± 0.130
Resting Heart Rate	73.254	0.138	73.16± 0.15	16.06 Hours ±1:32 hours	4.04± 1.41
Anaerobic Power	75.204	0.123	79.37± 1.088	16.46 Hours ±1 h 26m	4.641±1.539
Aerobic Power	91.78 *	0.02	50.93± 0.51	15.53 Hours ± 06 m	4.17± 0.72
Swimming Performance	74.455	0.12	31.26± 0.15	19.00 Hours ± 1.26hrs	0.63± 0.21

The results of cosinor analysis confirmed the existence of circadian rhythm in only two variables out of 5 selected variables such as body temperature (90.365% rhythm, at probability level 0.03) and aerobic power (91.18% rhythm at probability level 0.02). All the selected variables showed their peak that is., acrophase during evening hours 4 pm to 7 pm.

All the selected physiological variables such as body temperature, resting heart rate, anaerobic power and aerobic power which are primary sub domains of any sport performance, showed their peak during evening hours is followed by the peak performance of swimming.

DISCUSSION

From the results of the study, it is evident that there are significant differences in mean body temperature, resting heart rate, anaerobic power, aerobic power and swimming performance of higher secondary school boys among different times of the day. The circadian rhythmicity is found to be significant in body temperature and aerobic power at 0.03 and 0.02 level of significance respectively. Though the circadian rhythmicity of resting heart rate , anaerobic power and swimming performance are 73.254, 75.20 and 74.45 respectively they are not statistically significant.

The mean body temperature was significantly better at 6 pm (97.25 F) than at 2 pm(95.667 F) with the difference of 1.58 F. Cosinor analysis reveals that the body temperature did exhibit a significant circadian rhythm (90.37%) for the samples of higher secondary school boys. Moreover they have rhythm amplitude of (0.69F) and peak performance at 17.26 hrs.

The mean resting heart rate is significantly better at 6 pm (78 bt/min) than at 2 pm (67bt/min) with the difference of 11 bt/min). Though the samples show better circadian rhythm (73.25%) but not significant. Moreover the samples exhibited their rhythm amplitude of 4.04 and peak at 16.04 hours in resting heart rate.

The mean anaerobic power was significantly better at 6 pm (84.59 kg/met/sec) than at 2 pm (72.553 kg/mets/sec) with the difference of 12.04 kg/met/sec. Cosinor analysis reveals that the anaerobic power did exhibit better circadian rhythm (75.204%) but not significant for the sample taken. Moreover the Higher secondary school boys showed their rhythm amplitude of 4.64 and peak performance at 16.46 hours.

The mean aerobic power was significantly better at 6 pm (55.485 ml/kg/min) than at 2 pm.(46.173 ml/kg/min) with the diference of 9.312 ml/kg/min. Cosinor analysis reveals that the aerobic power exhibit a significant circadian rhythm (91.782%) for the samples of higher secondary school boys. Moreover, these boys have their rhythm amplitude of (4.17) and peak performance at 15.53 hrs.

The mean swimming performance was significantly better at 6 pm (30.88 sec) than at 2 pm (32.00 sec) with the difference of 1.2 sec. Cosinor analysis reveals that the swimming performance did exhibit a better circadian rhythm (75.46%) but not significant. The samples have their rhythm amplitude (0.63 sec) and peak performance at 19.00 hrs.

CONCLUSIONS

1. All then selected variables showed significant variation between different times of the day.
2. Circadian rhythm was significant in body temperature and aerobic power.
3. The peak times of all the selected variables for higher secondary school boys are same in the evening.
4. Resting heart rate, anaerobic power, aerobic power and swimming performance follow the body temperature rhythm which peaks in the evening and falls in the early morning for samples.
5. Since the best results of body temperature, resting heart rate, anaerobic power and aerobic power are primary sub domains of physical performance achieved in times between 3pm to 5.30 pm. It is understood that in this time the physiological variables are in close synchronization, which has linear trend with swimming performance.

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