Chapter I

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"To everything there is a season, And
A time to every purpose under the heaven"

Ecclesiastes. 3:1, Holy Bible, (1988)

Success in sports, as measured by competitive performance, is dependent upon a number of significant mental and physical components. Somato type, motor skills, age, nutritional status, physiology, psychology, training level, genetic endowment, and injury risk are the major variables influencing performance of sports persons. One such biological phenomenon influencing sports performance is "Circadian rhythm".

BIOLOGICAL RHYTHMS

When we are having a bad day we should not be too quick to blame our spouse, a mysterious virus or our unhappy childhood. We may simply feel out of sorts because we are trying to 'tick' when our body wants to 'tock'. In other words, one of our biological clocks may be out of synch with the others or with our surroundings.

We all have a complex system of hundred or more internal clocks that regulate everything from our heart rate and body temperature to reaction time and memory. Each clock runs
on its own cycle creating an inner symphony of biological rhythms that help us to adopt to a world that is itself constantly changing from day to night and season to season.

Forrester, (1985) reported that life as we know it, evolved on a planet that rotates on its polar axis every 23 hours 56 minutes and 4 seconds, to provide a diurnal cycle of day and night while it revolves around the sun once in 365.26 days to create a progression of seasons. At the same time the more complicated movement of the moon in relation to earth and sun produces our lunar month and the tidal cycles. The rotation of earth produces the continuous alteration of light and darkness. Around it our sleeping and waking and all our highly complex social lives are organised. So, early in the evolution the activity of individual cells begin to respond to the powerful and repetitive day and night cues.

Because of the regularity of cycles of light, temperature, and food availability, organisms that evolved temporal programs or endogenous rhythms of metabolism and behaviour providing anticipatory response to specific optional phases of environmental cycles were at a selective advantage. Thus, many biological rhythms reflect the period of one of four environmental cycles namely cycles of the tides, of day and night, of the phases of the moon, or of the seasons.
The prefix 'circa' has also been applied to other biological rhythms that synchronize with various other geophysical cycles for example circatida, circa lunar and circannual referring to the cycle of the tidal waves, the phases of moon and the season in a year respectively. The circadian rhythm is the most widely studied of these rhythms.

Robert Guinn (1986) reported that we become a different person throughout the day as each cycle goes through its peaks and valleys. Body temperature rises and falls by two degrees every day and blood pressure waxes and wanes by as much as twenty per cent. The daily alteration of sleep and wakefulness is accompanied by many changes including activities of nervous system and endocrine systems. There are daily variations also in the rate of hormonal synthesis and in cell divisions. One of the striking manners in which the presence of fundamental 24 hour variations reflected in man and other animals is in changing responsiveness or susceptibility to physical and chemical insults. For example, dose of powerful poisons fully lethal at one time of day, leave animals unharmed at another time.

Patton et al., (1989) in their text reported that such rhythmically occurring self-sustained rhythms in the various physiological parameters approximating the period of the earth's rotation with the period of approximately 24 hours were first termed
'Circadian' by Halberg in 1959 from the Latin 'Circa' meaning 'about' and 'dies' meaning 'day'.

The generation of these biological rhythms and integration of them with other physiological functions require the existence of biological 'pacemakers' or oscillators with time keeping capacity because the period of the circadian pacemaker is not exactly twenty four hours, it must be reset daily. The environmental cues that synchronise or entrain biological pacemakers have been given the name "Zeitgebers" (from the German meaning "time givers") and the process of resetting the pacemaker is called "entrainment" or "resynchronization". The light-dark cycle is a potent Zeitgeber for circadian rhythms in many organisms, but daily cycles in ambient temperature, food availability, social interactions and even electromagnetic field strength have been shown to entrain circadian rhythms. However in man such as knowledge of the time, and observance of customary hours for eating and for going to bed etcetera also play an important role.

A circadian rhythm is said to be exogenous when it disappears following the removal of the external influence that is its 'Zeitgeber' and reappears once it is reinstated. Examples for 'exogenous' circadian rhythm are sleep : wake cycles, oxygen consumption, respiratory frequency etcetera that disappear when 'Zeitgeber' like the knowledge of the time is removed.
A circadian rhythm is said to be endogenous when it is self-sustaining after the removal of all relevant 'Zeitgeber' and tend to free run and take on somewhat a longer period than 24 hours, usually about 25 hours. Examples for endogenous rhythms are body temperature, levels of circulating neutrophils, eosinophils, lymphocytes, corticosteroid output etcetera. These endogenous rhythms are affected only weakly by external influences.

However, the circadian rhythms do not exist in isolation from each other. They cannot be considered wholly exogenous or endogenous because interactions between different endogenous or exogenous rhythms also exist. Because of this mutual influence on one another it is difficult to study any particular rhythm in man separately. The studies on endogenous rhythms in man shows that there cannot be a single biological or internal 'master clock' which is capable of regulating all internal circadian rhythms. Studies reveal that the interaction between genetic and environmental components may be involved in the development of these rhythms.

**PHYSIOLOGY OF CIRCADIAN RHYTHM**

There are daily rhythms that affect the function of the lungs, cardiovascular rhythms, kidneys, blood flow, muscular activity and cognitive function. Health is now coming to be viewed
as a state when all the body's biological rhythms are closely "in sync". Desynchronization of these clocks can cause a variety of mental and physical problems, including depression, mental fogginess, memory loss, head aches, moodiness, short temper, tension, poor appetite, slow reflexes, fatigue weakness and off-schedule fowl movements.

In some animals there is a direct link between the suprachiasmatic nuclei and the retina. There is also evidence of a center in the lateral hypothalamic area with function related to circadian rhythm is core temperature and cross linked to the suprachiasmatic region. The pineal gland is sensitive to human circadian rhythm changes in light intensity during the day and important time keeping functions are attributed to it. In this gland light exerts time-giving properties via a special visual pathway that synapses with the suprachiasmatic nuclei. These rhythms may have been developed genetically and through environmental components.

In mammals, the suprachiasmatic nuclei of the hypothalamus in the fore brain have the properties of the circadian pacemakers. These nuclei are the clusters of small cells. There are lines of evidence that these nuclei maintain rhythmically in the absence of any input and are capable of driving rhythms in other tissues.
The central nervous structures involved in the chrono regulation of biological function are suprachiasmatic nuclei, olfactory bulbs, fornix, septum, limbic structure, hippocampus, preoptic area retinohypothalamic connection, midbrain raphe nuclei, ventromedial hypothalamus dorsomedial hypothalamus, locus coeruleus, brain stem, autonomic nervous system, superior cervical ganglic and pineal gland.

The study of biological clocks and circadian rhythm is known as chronobiology and is in its own rights a respected field of science. In the late 50's the theory of chronobiology stated that certain blood cells varied periodically by number, depending on the time of the day they were drawn from the body. From research stimulated by this theory, scientists found that rather than performing at a steady rate we are sometimes accelerating, sometimes slowing down. We achieve peak efficiency for only a limited time each day.

By applying cosinor - rhythmometry method, a circadian rhythm can be characterized by estimating three parameters such as Mesor, Amplitude and Acrophase. Mesor means acronym for Midline Estimating Statistic Of Rhythm i.e., the mean level of oscillation. Amplitude means the extent of oscillation from the Mesor or half of the total oscillation. Acrophase means timing of the crest of the wave form.
There is a daily rise and fall of blood pressure and excretion of sodium and potassium by the kidneys, as well as variations in reflex time, in sweating of the palm of the hand and in numerous other functions. Particularly noticeable one variation is body temperature which is about two degree Fahrenheit lower at night than during the day.

Likewise more than hundred physiological parameters have been influenced by the circadian rhythm. So it is not a wonder if the performances of human will also be influenced simultaneously.

It has been observed that the functional capacity in the case of human beings varies during the 24 hour cycle that is, there are times when athlete's performance is at the highest, at the lowest and may be moderate in between. It is also observed that through training the performance capacity can be modified so as to get the athlete perform at the best on the time when he is to be engaged in the competition.

Man's performance in sport or any other field depends on his movement oriented behaviour and all these actions have their roots in biological phenomena. This biological phenomena 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 be 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°C and 40°C respectively. The resting temperature is closest to these values in the evening.

Faster performance at the crest time of body temperature may be linked with local temperatures in active muscle and other soft tissues. A circadian variation has been 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 the peak in the afternoon.

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

Many human performance measures tend to follow closely the circadian rhythm in body temperature. If we trace the world record in athletics for the past 50 years, most of them are set in the late afternoon or evening. For example, world record performance by British athletes in track, distance races between 800m to 5000m took place between 19:00 and 23:00 hours that is when the ambient temperature and body temperatures are at their peak. Also athletes tend to prefer evening contests and consistently achieve their top performances at this time of day. The fact that freely chosen level of exercise 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. French international 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" practices are best timed for later in the day. It is accepted that sports performances is determined by many variables and there may be multiple performance rhythms. This can be further examined by looking at the existence of rhythms in components of sports performance.

COMPONENTS OF SPORTS PERFORMANCE INFLUENCED BY CIRCADIAN RHYTHM

PHYSICAL COMPONENTS

There is a circadian variation in trunk flexibility and hip flexibility. Circadian variation has also been found in lumbar flexion and extension, passive straight leg raising, glen humeral lateral rotation, and the distance from finger tip to floor in forward flexion. Isometric muscle force, dynamic muscle activity, neuromotor performance, and gross motor performance are all subjects to circadian rhythms. The timing of the peaks tends to follow the phase of the body temperature curve, although this does not imply that they are caused by the changes in temperature.
Rhythms in grip strength and back strength have been replicated in dynamic muscular activity such as the vertical jump, and the standing broad jump. The variation in such tests attributable to time of day ranges from about three per cent of the mean value for jumping to 6 to 10 per cent for isometric strength to about 15 per cent of power output on a swim-bench. The amplitude of the rhythm increases with increasing complexity of the task. Although seemingly small in magnitude, an improvement of the order of three per cent can have a profound effect on competitive performance.

The rhythm in muscular strength is robust and persists under conditions where subjects are deprived of sleep for four consecutive nights. The circadian variation in grip strength is greater than the effects of sleep loss on this function. Although the normal rhythm in muscular strength is in phase with that of body temperature, the extent to which alterations in muscle temperature or in motivation of subjects contribute to the rhythm is not clear.

Muscle performance is optimal at a muscle temperature of around 39°C and a core temperature of 38.3°C. Competitive athletes may elevate muscle temperature to this level as a result of warming up and so might over-ride an inherent rhythm in muscle performance.
PHYSIOLOGICAL COMPONENTS

Many physiological functions are known to show circadian rhythmicity. They include metabolic, cardiovascular, and endocrine functions. The metabolic functions showing cyclical changes include oxygen consumption $V_{O_2}$max carbon dioxide production $V_{CO_2}$ and minute ventilation $V_E$. The rhythms in $V_{O_2}$ and $V_{CO_2}$ have an amplitude of about seven per cent of their mean resting value, whereas that in $V_E$ is about 11 per cent. Only about one-third of the variations in metabolism can be explained by the circadian rhythm in body temperature, despite the fact that the peaks occur close together in time. In leg exercise the anaerobic capacity (as measured by the Wingate test) is reduced by eight per cent at 06:00 hours compared with 14:00 hours whereas the peak power value is maintained well, a decline in performance during the 30-s test suggests a motivational component in the circadian variation in anaerobic capacity.

Cardiovascular functions also display a rhythm similar in shape to the body temperature curve. The rhythms in adrenaline and nonadrenaline are the most closely related to the performance curve. The excretion of electrolytes is also closely related in phase to the body temperature and performance rhythms.
The circadian rhythm in VE, which is apparent during light and moderate exercise, similarly disappears under maximal aerobic conditions, at least for leg exercise. During performance of arm ergometry the VO₂ peak and highest heart rate demonstrate a circadian rhythm, the highest values being observed close to the crest time of rectal temperature. The results reflect a rhythm in the total work performed.

**PSYCHOLOGICAL COMPONENTS**

We experience "moods" constantly throughout our day. We like being in a "good mood" and we dislike being in a "bad mood". Moods color our perception. If we are in a good mood, we interpret our environment through rosy glasses; even irritating or disappointing events are viewed more benevolently. It is more than a feeling or an emotion. It lasts longer and is more pervasive. It affects our feelings by shading our perceptions. Mood is both a psychological and a physical phenomenon. It happens in our minds and in our bodies.

The time of the day affects the energy of the body. The circadian rhythm inherent in the body gives rise to different energy levels throughout the day. Everyone's circadian rhythms are different, but one very common pattern is that in which there is a natural high energy in the late morning or early afternoon.
and again (to a lesser extent) in the early evening. In the late afternoon (around 4:00 pm) and in the evening (9:00 to 11:00 pm) there is a dip in the energy.

This rising and falling energy is closely associated with mood, so that a person with this common circadian rhythm might wake up in a low energy state feeling slightly anxious or depressed might feel increasingly positive and energetic as the morning progresses, start to feel tired and down in the late afternoon, pick up again for a while after dinner, and then get tired and grumpy in the late evening. All this would happen regardless of outside "events". They are happening inside the body.

Research has shown that when we are in a low point in our circadian rhythm, we tend to view our actual problems in a more serious and depressing light. Mood affects the way we look at our problems. When our mood is good - life is pleasurable and problems seem manageable.

Mood (a summary score created from the POMS, tension, anxiety, depression, anger, fatigue, and confusion subscales) exhibited a circannual pattern with peaks during the months of November and July and a trough during the months of March and April.
Significant time of day effects were found in the mood variables of alertness, sleepiness, weariness, effort required happiness and well being. Times of best mood were different from the time of peak temperature.

Rhythms have been identified sensory motor (reaction time), psychomotor (hand-eye co-ordination), sensory perceptual, cognitive, and psychological functions.

**INDIVIDUAL DIFFERENCES**

There is some evidence that the phasing of circadian rhythms is affected by personality. Introverts tend to be better performers in the morning, whereas extroverts are more sluggish at this time. They make up for this by reaching a peak level of performance later in the day and staying alert for longer in the evening. The body temperature curves of these different personalities show a similar form, but that of the introvert peaks earlier in concordance with the performance curves.

The scope of this study is to analyse the circadian rhythm on selected variables which have the main contributions of sports performance. Each variable has its own peak time and trough time. This will also vary individual to individual. 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 the
better time for peak performance of that particular individual or group.

Circadian rhythmicity of many variables has been established in previous research works. Not much works have been carried out to find to what extent these rhythmicity varies between trained people and untrained people. There is no notable research works in this area conducted to analyse the circadian rhythmicity on physical, physiological and psychological variables in a combined way and among group of both trained and untrained human.

Moreover, studies on circadian rhythm of mood states of athletes are also done to a lesser extent and the results are equivocal.

If we have the knowledge of peak time for performance of an individual then we can go accordingly to plan training methods and strategies to improve further and exhibit on highest performance in the competition.

**STATEMENT OF THE PROBLEM**

The purpose of the study was to analyse the influence of Circadian Rhythm on Selected Physical, Physiological and Psychological Variables of trained and untrained males.
DELIMITATIONS

The study was delimited in the following factors.

1. To achieve the purpose of the study, ten physically trained students studying Masters degree in physical education at Dr. Sivanthi Aditanar College of Physical Education, Tiruchendur and ten physically untrained students studying Masters degree in Arts and science at Aditanar College of Arts and Science, Tiruchendur, TamilNadu were selected as subjects.

2. The study was confined to the male players only.

3. It was confined to physical, physiological and psychological variables such as; Grip strength, Flexibility, Muscular endurance, Speed, Body temperature, Resting Heart Rate, Anaerobic power, Aerobic power, Reaction time, and Profile of mood states which are the primary sub domains of human performance as dependent variables.

4. The following standardized tests were conducted to assess the selected variables. Grip strength, Flexibility, Muscular endurance, Speed, Anaerobic power, Aerobic power, Reaction time and Profile of mood states, were assessed by Grip dynamometer, Sit and reach test, Bent-knee sit ups, 50 metres run, Margaria Kalamen stair run test, Queen's college step test, Reaction timer and POMS Questionnaire respectively. Body temperature and Resting Heart Rate were recorded by Biomonitor.
5. The instruments and facilities available at Dr. Sivanthi Aditanar College of Physical Education, Tiruchendur, TamilNadu, were used to assess the selected Physical, Physiological and Psychological variables.

6. The various time points selected for collection of data were 02:00, 06:00, 10:00, 14:00, 18:00 and 22:00 hours.

LIMITATIONS

The following limitations were considered while interpreting the results of the study.

1. The weather conditions such as atmospheric temperature, humidity, exposure of light and dark and meteorological factors during testing period were not considered.

2. Though the subjects were motivated verbally, no attempt was made to differentiate the motivation level during the period of testing.

3. Since the manual operation was made during 50 meter run, the time was recorded in one tenth of a second.

4. Since the subjects were made to stay in the Human Performance Laboratory of Dr. Sivanthi Aditanar College of Physical Education, Tiruchendur and were asked to do the tests even during night times, the psychological factors involved in their process could not be ascertained.
5. No effort was made to control or assess the quantum of the food ingested, life style, and other factors that affect metabolic function.

6. The investigator made an attempt to avoid, practice effort, familiarity with the tests and serial fatigue while conducting the tests, however no attempt was made to find out whether the above said factors influenced the performance of the subjects.

**HYPOTHESES**

1. There may be a significant difference on selected physical, physiological and psychological variables between trained and untrained males irrespective of different times of the day.

2. There may be a significant difference on selected physical, physiological and psychological variables between different times of the day irrespective of training status.

3. There may be a significant difference on selected physical, physiological and psychological variables among trained and untrained male on different times of the day.

4. There may be a significant circadian rhythmicity in selected physical, physiological and psychological variables of trained and untrained males.
SIGNIFICANCE OF THE STUDY

The competitive nature of human being is as old as his origin: "Every individual or nation wants to establish his or her supremacy over other individuals or nations. This fact stimulates, inspires and motivates everyone to sweat and strive to run faster, jump higher, throw farther and exhibit various motor skills in the present international sports arena. In many athletic events a centimetre or a millisecond makes the difference among the individuals in achieving medals.

The zone of peak performance is defined as the ideal psychological, physiological, and physical state commensurate with a level of optimum attainment for a particular individual. This zone of peak performance may vary for variable to variable and individual to individual in a 24 hours day.

Therefore the findings of this study will be of significance in the following ways.

1. The findings of this study may add to the existing fund of knowledge with regard to the circadian rhythm on the selected physical, physiological and psychological variables.

2. The results of the study may provide guidelines, which will help the Physical Educators and Coaches in preparing
the training schedules for trained and untrained athletes in their respective sports.

3. The results of the study may help the Physical Educators and Coaches to find out the zone of peak performance i.e. time in which the peak value of circadian rhythm of factors determine sports performance.

4. The findings of this study will add to the quantum of knowledge in the area of Sports Physiology and Training Methods.

DEFINITION OF OPERATIONAL TERMS

CIRCADIAN RHYTHM

Pertaining to any biological cycle (example of varying intensity of metabolic or physiological process, or some features of behaviour) which is repeated usually approximately every twenty four hours.

Such rhythmically occurring self-sustained rhythms in the various physiological parameters approximating the period of the earth's rotation with the period of approximately twenty four hours were first termed 'circadian' by Halberg in 1959 from the Latin 'circa' meaning 'about' and 'dies' meaning 'day'.
GRIP STRENGTH

It may be defined as the capacity of person to exert muscular force of the palm.

FLEXIBILITY

Flexibility is the range of movement in joints.

MUSCULAR ENDURANCE

The ability of a muscle or group of muscles to overcome resistance or to act against resistance for longer duration under conditions of fatigue or tiredness.

SPEED

The capacity of moving a limb or part of the body's lower system or the whole body with the greatest possible velocity.

BODY TEMPERATURE

Body Temperature is the constant range of temperature needed for the proper functioning of the various systems of the body.

The typical body temperature of man lies between 97.7°F to 99.5°F. Body temperature is typically expressed in terms of the core temperature and it is usually measured orally. It reflects
the metabolic rate and the balance between heat production and heat loss.

**RESTING HEART RATE**

The heart rate or heart frequency is defined as the frequency of heart beats in one minute, when a player is in resting conditions.

**ANAEROBIC POWER**

The maximum rate of energy release for muscle work.

**AEROBIC POWER**

Maximal rate at which an individual can consume oxygen during the performance of all-out, exhaustive, "best" index of cardio respiratory fitness.

**REACTION TIME**

Reaction time is the time taken to react or to oppose or defend a particular action. In other words it is a reflex action which is the interval between one set of stimulus and one set of response.

**MOOD STATES**

Transient, fluctuating affective emotional states.