Chapter II

REVIEW OF RELATED LITERATURE

The Research scholar taxed his limits and made sincere efforts to locate and collect the literature relevant to this study. However, there was very little he could locate & collect from the different library sources. A few references were made in different sources for some relevant studies but the details of the same were not available and as such could not be considered. Whatever collected has been presented in the form of review of literature in this study.

David and Moore, et.al.¹ Determined if there is diurnal variation in responses during high intensity constant power cycle ergometry. A second purpose was to investigate a possible relationship between individual changes in mood state and in response to exercise. Thirteen college students volunteered: four women of mean (±SD) age 23±3 year, height 168±7 cm and 840.5±13.5 kg. Subjects reported to the laboratory three times to complete profile of mood states (PPOMS) questionnaires and to perform exercise tests. The first test served as a learning trial and data were not used in analysis. The second and third

tests were randomly scheduled one at 8.00 a. m. (AM) and at 4.00 p.m. (PM) and results were compared for evidence of an effect of time of day. POMS were completed with the "Right Now" direction set. Exercise performance was evaluated by time to exhaustion in constant power cycle ergometry. (3.0WKg-1 for women and 3.5 WKg-1 for men). Time to exhaustion was 9.2% greater (P=0.04) in the PM (199±76s) than in the AM (182±71S). Maximal aerobic power, peak O2 was 7.61 higher (P=0.01) in the PM (3.55±1.081min-1) than AM (3.30±0.901min-1). Anaerobic capacity O2 deficit appeared to be but was not statistically 9.3% higher in the PM (5.431) than in the AM (4.971). Post exercise blood lactate (n=9) also tended to be higher in the PM (13.1mM±2.7) than AM (11.3mM±2.7). Only the POMS vigor subs ore was different (P <0.1) in the AM (9±7) and PM (14±).

Intra individual AM-PM differences in peak O2 and O2 deficit were related to differences in vigor (r=0.54; r=0.48). These results demonstrate the association between markers of psychological state and certain physiological measures. The findings confirm previous reports of a circadian rhythm in high intensity exercise performance. In addition, our data suggest that the difference in performance reflect diurnal variation in both maximal anaerobic power and anaerobic capacity.
Edwards B.J., et.al.² Studied that the normal circadian rhythm in exercise performance may be altered by the habitual timing of training. We have investigated if morning time trial performance is affected by the time at which moderate exercise is performed on the previous day. Eight male cyclists undertook two separate exercise sessions of sub-maximal cycle ergometry (60% V.O2peak for 30 min) at 07:00 h and 12:00 h the day before a 16.1-km time trial at 07:00 h. Heart rate, power output, ratings of perceived exertion, and rectal temperature were measured at rest and every 5 min in the pre-time trial exercises, and every 1.61 km during the time trial. Blood samples were taken at rest and immediately after the time trial for the measurement of lactate concentration. The time trial performed the day after the 07:00 h sub-maximal exercise was completed in 1672±135 s, compared to 1706±159 s for the time trial performed the day after the noon pre-time trial exercise (p=0.027). The time trial after exercise the previous morning was associated with higher work-rates (p=0.031), a higher net lactate accumulation after the time trial (p=0.018), and a trend for higher heart rates (p=0.093) compared to the time trial after exercise the previous noon. These findings suggest

that cycling performance in an early morning time trial is improved if an athlete participates in early-morning rather than noontime moderate exercise the day before. This finding cannot be attributed to the physiological responses to the exercise on the pre-time trial day or to environmental factors. It is suggested that it might partly reflect an advantage gained by performing exercise in the day(s) immediately beforehand at the same time as the competition.

Atkinson G. et. al. examined the effects of time of day on a cycling time trial with and without a prolonged warm-up, among cyclists who tended towards being high in "morning ness". Eight male cyclists (mean ±s: age = 24.9 ±3.5 years, peak power output = 319 ±34 W, phonotype = 39 ±6 units) completed a 16.1-km time trial without a substantial warm-up at both 07:30 and 17:30 h. The time trial was also completed at both times of day after a 25-min warm-up at 60% of peak power. Power output, heart rate, intra-aural temperature and category ratings of perceived exertion (CR-10) were measured throughout the time trial. Post-test blood lactate concentration was also recorded. Warm-up generally improved time trial performance at both times of day (95% CI for improvement = 0 to

---

30 s), but mean cycling time was still significantly slower at 07:30 h than at 17:30 h after the warm-up (95% CI for difference = 33 to 66 s). Intra-aural temperature increased as the time trial progressed (P < 0.0005) and was significantly higher throughout the time trials at 17:30 h (P = 0.001), irrespective of whether the cyclists performed a warm-up or not. Blood lactate concentration after the time trial was lowest at 07:30 h without a warm-up (P = 0.02). No effects of time of day or warm-up were found for CR-10 or heart rate responses during the time trial. These results suggest that 16.1-km cycling performance is worse in the morning than in the afternoon, even with athletes who tend towards 'morning ness', and who perform a vigorous 25-min warm-up. Diurnal variation in cycling performance is, therefore, relatively robust to some external and behavioral factors.

Smit S. et.al.\(^4\) Reported that Narcolepsy is associated with lowered vigilance. Diurnal variation in vigilance appears altered, but the exact nature of this change is unclear. It was hypothesized that the homeostatic sleep drive is increased in narcolepsy. Decreased levels of vigilance are reflected in low frequency band power in the electroencephalogram (EEG), so these frequencies were expected to

be increased in the narcolepsy group. Furthermore, it was expected that low frequency power should increase over the day. Narcoleptic patients and healthy controls participated (36 participants in total); they were not allowed to take medication or naps on the experimental day. EEG was measured at 9:00, 11:00, 13:00, 15:00, and 17:00 hours, during rest and during reaction time tasks. In the narcolepsy group, alpha power was lower at rest at all times. Delta and theta power during rest and task performance increased steadily over the day in this group, from 11:00 hours onwards. Additionally in the narcolepsy group beta2 power during rest appeared increased at the end of the day. The effects in the lower frequency bands strongly suggest that vigilance is low at all times. The progressive increase in low frequency power indicates that the sleep drive is enhanced. It is not whether this pattern reflects an extreme state of low vigilance, or a pathological brain condition. The effects in the higher frequencies suggest that narcoleptic patients may make an effort to counteract their low vigilance level.

Doust E. and Jonathon V., et al\textsuperscript{5} examined the variability of the oxygen uptake (V [O.sub, 2]) kinetic response during moderate and

high intensity treadmill exercise within the same day (at 06:00, 12:00 and 18:00 h) and across days (on five occasions). Nine participants (age 25 [+ or -] 8 years, mass 70.2 ± 4.7 kg, V_{O_{2}} \text{max} \text{[O.sub.2 max]} 4137[+ or -] 697 \text{ml} \times \text{[min.sup.-1]; mean [+ or -] s}) took part in the study. Six of the participants performed replicate ‘square wave’ rest-to-exercise transitions of 6 minute duration at running speeds calculated to require 80% V_{O_{2}} \text{max}[O.sub.2] at the ventilatory threshold.

Arnett M.G., et.al.⁵ Studied the effect of prolonged and reduced warm-ups on diurnal variation in body temperature and swim performance. Previous studies have suggested a diurnal variation in the performance of physical tasks. The theoretical basis for the effect of time of day on performance centers on the circadian rhythms of many physiological variables and especially the body temperature curve. This investigation had two purposes:

1. To determine if increasing the volume of the warm up could eliminate diurnal variation in body temperature and swim performance, and

⁵ M.G.Arnett et.al. “Effect of Prolonged and Reduced Warm Ups on Diurnal Variation in Body Temperature and Swim Performance”, Journal of Strength Conditioning and Research, 2002; 16(2): 256-61
McLevan T.M., et al. Studied diurnal effects on thermoregulation or tolerance of uncompressible heat stress. The study examined whether the lower rectal temperature (Tre) in the morning hours would increase tolerance to uncompressible heat stress compared with trials conducted in the early afternoon. Nine males (34 kg, 82kg, 2.0m square surface area) performed a formularization trial and then two randomly ordered trials in the morning (0930h) and afternoon (1330h). The heat stress test consisted of intermittent walking at 3.5km/h and scated rest at 40 degree C and 30% relative humidity while wearing nuclear, biological and chemical protective clothing. Initial Tre was significantly higher during the afternoon (37.1±0.2 degree C) compared with morning (36.8±0.2 degree C) versus the morning (39.0±0.3 degree C) trials. Metabolic rate, heart rate and sweat production rate were similar during the morning and afternoon exposures. Since the rate of heat storage (100.6±W/m square and 96.5±21.2 W/m square) for the morning and afternoon trials, respectively and tolerance time (1±22 and 107±19 min for the morning and afternoon trials respectively) were similar calculated total heat storage was also similar for the morning (16.1±2.9kj/KG). It was

2. To determine if reduction of the warm up volume in the late afternoon would affect body temperature and swim performance.

Participants for this investigation included 6 male and 4 female competitive swimmers (mean age = 15 +/- 1 years). Before the swim performance trials in the morning, participants warmed up with either standard volume (2,011.68,) or 200% of that volume. Before the afternoon swim performance trials, warm up volumes were either 33 % or 100% of the standard warm-up volume. Before entering the water and immediately after the warm up, temperature was taken from the ear. After the swim performance, participants were asked to rate their perceived exertion on the basis of Borg’s CR-10 rating scale. The order of test administration for time of day and warm up condition was balanced and with tests carried out over 4 days. Each swimmer completed 1 test condition (warm up) per day. Results indicated that increased morning warm up time eliminated diurnal variation in body temperature; however, evening superiority in swimming performance was not eliminated. The results also indicated that reducing the volume of the afternoon warm up to 33 % of the standard warm-up had no effect on body temperature or swim performance.
concluded that trials conducted in the early afternoon were associated with an increased rectal temperature tolerated at exhaustion that affect the circulation influence on rest rectal temperature, and thus, maintained tolerance times similar to trials conducted in the morning.

Atkinson G. and Spears L.,et.al. 8 Studied diurnal variation in tennis service with informed consent, 6 competitive tennis players performed alternate 15 “first” (emphasis-speed) serves and 15 “second” (emphasis- accuracy) serves at 09:00, 14:00 and 18:00 hours. Serve velocity was measured by the digitization of video footage of each serve. The Hewitt Tennis Achievement Test was employed to measure the accuracy of serve. The amount of spin imparted on the ball was not measured. First serves were at all times of day faster than second serves. First serves were faster but least accurate at 18:00 hours, the time of day that body temperature and grip strength were highest. At 09:00 hours, first serves were just as accurate as second serves, even though velocity of first serves was higher. No effects for time of day were found for the speed and accuracy of second serves. These results indicate that time of day does

---

affect the performance of tennis serves in a way that suggest a non linear relationship between velocity and accuracy.

Reilly T. and Garret R., et.al\(^9\) Investigated diurnal variation in sustained exercise performance. Human performance generally varies in phase with the circadian curve in body temperature. This relationship between performance and core body temperature may be disrupted when exercise causes a pronounced rise in body temperature. In this study the authors compared responses to exercise in the morning and in the evening when pre exercise body temperature differed significantly. Rectal temperature was measured pre exercise and throughout a cycle ergometer test at 70% Vo2 max in seven males (aged 19- 24 years). The test was performed at 08:30 and 17:30h, balanced for order with 3 days minimum between tests. Onset of sweating, weight loss and time to exhaustion were recorded. Metabolic measures (VO2, VE and RER and Heart Rate were recorded pre exercise and during exercise. Rectal Temperature and Skin Temperature at three sites were also measured. Rectal Temperature and Heart Rate were lower in the morning than in the evening by 0.6C and 7 beats min -1 (P<0.01), respectively. The lower

body temperature in the morning persisted throughout exercise, the final rectal temperature being 38.6 (SD = 0.2) C in the morning and 39.2 (SD = 0.5) in the evening. No effects of time of day were observed for VO2, VE, and RER but heart rate values during exercise were lower in the morning for 30 min (P<0.05). Sweat onset occurred sooner at 08:30h (7.57, SD = 0.90 min) compared to 17:30h (8.71, SD = 2.20 min) (P<0.05). Time to exhaustion ranged from 48 to 72 min, but did not vary with time of day (P<0.05). It is concluded that morning timing does not necessarily disadvantage continuous sub-maximal exercise

Gintchin L.D., et.al\textsuperscript{10} Studied diurnal variation in strength and endurance performance among resistance trained males. Circumstances dictate that athletes train at various times during the day. The question arises whether the time of day effect the performance quality during resistance training. The purpose of this study was to determine the effect of time of day on muscular strength and endurance work out put in resistance-trained subjects. Twenty-two college-aged males were measured at 6:00 am. Test order was randomized and counterbalanced. One group (n=12) had routinely

weight trained at 6:00 am. 3 ×/wk at 5:00 pm for the previous 6 months.

<table>
<thead>
<tr>
<th></th>
<th>AM Trained</th>
<th>PM Trained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 am</td>
<td>5 pm</td>
</tr>
<tr>
<td>Trial</td>
<td>105.9±14.2</td>
<td>104.5±10.1</td>
</tr>
<tr>
<td>1-R-M Bench</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press (kg)</td>
<td>108±2.7</td>
<td>9.7±2.7</td>
</tr>
<tr>
<td>Repetition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 75% RM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A 2×2 ANOVA revealed non-significant F- ratio for 1-RM between groups (F = 0.38) and for time of day (F = 0.11). The interaction was also non significant (F = 0.05). The same pattern was noted for repetitions for groups (F = 0.55), time of day (F = 0.65) and interaction (F = 0.31). In conclusion, maximal strength and muscle endurance performance do not appear to be greatly affected by time during the day when measured in the resistance trained individuals.
Nicolas A. Gauthier A., et al.11 Conducted study to examine the time-of-day effects on muscle fatigue and recovery process following an isometric fatiguing contraction. Sixteen male subjects were tested at two times (06:00h and 18:00h) and were requested to perform a sustained sub maximal contraction of the elbow flexors, consisting in maintaining 40% of their absolute strength as long as they could. Isometric maximal voluntary contractions (MVC) were performed before (Pre), immediately after (Post), and up to 10min after the endurance task. Endurance time, peak torque (PT) and electromyography (EMG) activities of the biceps brachia and triceps brachia were recorded and analyzed. Results showed that under Pre-test conditions, PT developed at 18:00h was higher than at 06:00h. No time-of-day effect appears for the endurance time and EMG activities during the test. No time-of-day effect was observed on either MVC or EMG recovery. From the results of this study, it seems that both muscle fatigue and recovery process are not time-of-day dependent. We conclude that circadian rhythm of the force does not influence the evaluation of muscle capacities during a sub maximal exercise corresponding at 40% of MVC.

Waterhouse J.T.et.al.\textsuperscript{12} Reviewed the circadian rhythm of core temperature: origin and some implications for exercise performance. This review first examines reliable and convenient ways of measuring core temperature for studying the circadian rhythm, concluding that measurements, but that insulated axilla temperature does not. 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 vasodilatation of the cutaneous vasculature. Difficulties arise when the rhythm of core temperature is used as a marker of the body clock, since it is also affected by the sleep-wake cycle. This masking effect can be overcome directly by constant routines and indirectly by purification methods, several of which are described. Evidence supports the value of purification methods to act as a substitute when constant routines cannot be performed. Since many of the mechanisms that rise to the circadian rhythm of core temperature are the same as those that occur during thermoregulation in exercise, there is an interaction between the two. This interaction is manifest in the initial response to spontaneous activity and to mild exercise, body temperature rising more quickly and thermoregulatory reflexes being

recruited less quickly around the trough and rising phase of the resting temperature rhythm, in comparison with the peak and falling phase. There are also implications for athletes, who need to exercise maximally and with minimal risk of muscle injury or heat exhaustion in a variety of ambient temperatures and at different times of the day. Understanding the circadian rhythm of core temperature may reduce potential hazards due to the time of day when exercise is performed.

Waterhouse J.et.al. Conducted study one eight healthy subjects exercised at 90 watts on a cycle ergometer on four occasions, at times close to the minimum, maximum rate of rise, maximum, and maximum rate of fall of their resting core temperature. The duration of exercise was determined by the time taken for the core (rectal) temperature to reach an equilibrium value. Forearm skin blood flow and temperature were measured regularly during the exercise, as were heart rate and ratings of perceived exertion. Sweat loss was calculated by weighing the subjects nude before and after the exercise. The rise of heart rate was not significantly different at the four times of exercise, though the rating of perceived exertion was greatest at 05:00 h. Resting core temperatures showed a significant circadian rhythm at

rest (the timing of which confirmed that exercise was being performed at the required times), but the amplitude of this rhythm was decreased significantly by the exercise. The initial rate of rise of core temperature, and the total rise from the resting to the equilibrium value, was both inversely proportional to resting temperature. A negative-exponential model accurately described the time-course of the rise, but this model gave no evidence that the kinetics of the equilibration process depended upon the time of day. The thermoregulatory responses to the rise in core temperature—the amount of total sweat loss and rises in forearm skin blood flow and temperature—differed according to the time of exercise. In general, the responses were significantly greater at 17:00h compared with 05:00h, and at 23:00 h compared with 11:00 h. The results accord with predictions made on the basis of previous work by us in whom core temperature rhythms have been separated into components due to the endogenous body clock and due to the direct effects of spontaneous activity. The results are discussed in terms of the ecological implications of the differing capabilities of humans to deal with heat loads produced by spontaneous activity or mild exercise at different phases of the circadian rhythm of resting core temperature.
Souissi N. et al. Previous studies investigating the impact of circadian rhythms on performance during anaerobic cycle leg exercise have yielded conflicting results. The purpose of the present investigation was firstly, to determine the effect of the time of day on anaerobic performance during a force-velocity test on a cycle ergometer (F-V) and the Wingate test and secondly, to relate any changes in anaerobic performance to the circadian rhythm in oral temperature. Nineteen subjects volunteered to take part in the study. In a balanced and randomized study design, subjects were measured for maximal power (P (max)) (force-velocity test), peak power (P (peak)) and mean power (P (mean)) (Wingate test) on six separate occasions. These were at 02: 00, 06: 00, 10: 00, 14: 00, 18: 00 and 22: 00 hours on separate days. There was an interval of 28 h between two successive tests. Oral temperature and body mass were measured before each test. Body mass did not vary during the day but a significant time of day effect was observed for the oral temperature with an acrophase at 18: 22 ± 00: 34 hours. A significant circadian rhythm was found for P (max) with an acrophase at 17: 10 ± 00: 52 hours and amplitude of 7%. A time-of-day effect was significant for F (0) and V (0). Also a

significant circadian rhythm was observed for P (peak) with an acrophase at 17: 24 ± 00: 36 hours and an amplitude of 7.6 % and for P (mean) with an acrophase at 18: 00 +/- 01: 01 hours and an amplitude of 11.3 %. The results indicated that oral temperature, P (peak), P (mean) and P (max) varied concomitantly during the day. These results suggest that there was a circadian rhythm in anaerobic performance during cycle tests. The recording of oral temperature allows one to estimate the time of occurrence of maximal and minimal values in the circadian rhythm of anaerobic performance.

Duffy D.J.et.al.15 Studied on getting through to circadian oscillators: why use constant routines. Overt 24 h rhythmicity is composed of both exogenous and endogenous components, reflecting the product of multiple (periodic) feedback loops with a core pacemaker at their center. Researchers attempting to reveal the endogenous circadian (near 24-h) component of rhythms commonly conduct their experiments under constant environmental conditions. However, even under constant environmental conditions, rhythmic changes in behavior, such as food intake or the sleep wake cycle; can contribute to observed rhythmicity in many physiological and

endocrine variables. Assessment of characteristics of the core circadian pacemaker and its direct contribution to rhythmicity in different variables, including rhythmicity in gene expression, may be more reliable when such periodic behaviors are eliminated or kept constant across all circadian phases. This is relevant for the assessment of the status of the circadian pacemaker in situations in which the sleep wake cycle or food intake regimes are altered because of external conditions, such as in shift work or jet lag. It is also relevant for situations in which differences in overt rhythmicity could be due to changes in either sleep oscillatory processes or circadian rhythm city, such as advanced or delayed sleep phase syndromes, in aging or in particular clinical conditions. Researchers studying human circadian rhythms have developed constant routine protocols to Assess the status of the circadian pacemakers in constant behavioral and environmental conditions, whereas this techniques is often thought to be unnecessary in the study of animal rhythms. In this short review, the authors summarize constant routine methodology and what has been learned from constant routine and argue that animal and human circadian rhythm researchers should (continue to) use constant routines as a step on the road to getting through to central and peripheral circadian oscillators in the intact organism.
Yougstedt S.D.et.al.\textsuperscript{16} Studied regular exercise effects on the circadian rhythm. Physically active young adults ($M = 14; F = 21$) and older adults ($M = 12; F = 21$) were observed over a period of four to five days following a 90-minute "ultra-short" sleep-wake cycle (30 min sleep, 60-min wake). Baseline circadian rhythm was assessed over 30 hours. During the following three day's were exposed to experimental phase-shifting treatments (randomly assigned exercise or bright light), centered at one of eight randomly assigned times around the 24 hour day. Treatments were one hour of treadmill exercise at 60-70\% VO2 peak, and three hours of bright light. It was found that exercise had a similar influence on circadian rhythms, as did bright sight. Regular exercise affects the circadian rhythm.

Callard D. et.al\textsuperscript{17} This study deals with the influence of time of day on neuromuscular efficiency in competitive cyclists during continuous exercise versus continuous rest. Knee extension torque was measured in ultra distance cyclists over a 24h period (13:00 to 13:00 the next day) in the laboratory. The subjects were requested to maintain a constant speed (set at 70\% of their maximal aerobic speed


obtained during a preliminary test) on their own bicycles, which were equipped with cyclosimulators. Every 4h, torque developed and myoelectric activity was estimated during maximal isometric voluntary contractions of knee extensors using an isokinetic dynamometer. Mesenteric temperature was monitored by telemetry. The same measures were also recorded while the subjects were resting awake until 13:00 the next day. During activity, torque changed within the 24h period (p < .005), with an acrophase at 19:10 and an amplitude of 7.8% around the mean of 70.7%. At rest, a circadian rhythm was observed in knee extensor torque (p<0.05), with an acrophase at 19:30 and an amplitude of 6% around the mean of 92.3%. Despite the standardized conditions, the results showed that isometric maximal strength varied with time of day during both a sub maximal exercise and at rest without prior exercise. The sine waves representing these two rhythms were correlated significantly. Although at rest the diurnal rhythm followed muscular activity (i.e., neurophysiologic factors), during exercise, this rhythm was thought to stem more from fluctuations in the contractile state of muscle.
Hill D.W., et al. The purpose of this study was to determine whether metabolic and cardio respiratory adaptations to exercise training are greater at the time of day of training than at another time. Twenty-seven subjects performed cycle ergo meter tests in the morning (AM) and in the afternoon (PM) before and after a 6-wk period during which ten subjects trained regularly in the morning, seven subjects trained in the afternoon, and ten did not train. Training caused decreases in HR, VE, and rating of perceived exertion during sub-maximal exercise; a 7.7% increase (p < 0.01) in VO2 max; and a 9.1% increase (p < 0.01) in performance time. Adaptations (training effects) were independent of time of day of training for all variables except VO2 at the ventilatory threshold. Compared with each other, subjects who trained in the morning had relatively higher post-training thresholds in the morning, while subjects who trained in the afternoon had relatively higher values in the afternoon (p <0.05). This is evidence of circadian specificity in training and supports the notion of planning physical preparation to coincide with the time of day at which one's critical performance is scheduled.

Duffy J.F., et al\textsuperscript{19} Studied the relationship of endogenous circadian melatonin and temperature rhythms to self reported preference for morning or evening activity in young and older people. Morning ness- evening ness refers to inter-individual differences in preferred timing of behavior (i.e. bed and wake times). Older people have earlier wake times and rate themselves as more morning-like than young adults. It has been reported that the phase of circadian rhythms is earlier in morning types than in evening types, and that older people have earlier phases than young adults.

Dalton B.W. et al\textsuperscript{20} Conducted a study to determine if circadian rhythms have an effect on time trial cycling performance of 15 min duration. Seven males (Mean ± SD): age, 22.3±4.9 yr; height 179.0±7.9 cm, body mass 74.5±15.5 kg; VO2 max 68.0 5.7 ml × kg (-1) × min (-1) who were all competitive cyclists or tri-athletes with previous experience in laboratory testing procedures volunteered to participate in this study. Each of the seven subjects underwent a series of four tests; one VO2 max test, and three 15 min maximal performance tests, at varying times during a 24 hr period. Testing

\textsuperscript{19} J.F. Duffy et al., "Relationship of Endogenous Circadian Melatonin and Temperature Rhythms to Self Reported Preference for Morning or Evening Activity in Young and Older People", Journal of Investigation Medicine, 1999; 47(3): 141-50

times were at 08.00-10.00; 14.00-16.00 and 20.00-22.00 hours. Heart rate was recorded during the last 10-15 seconds of each minute and blood lactate levels were taken at 5 and 10 min during exercise and again immediately post-exercise. O2 consumption was measured continuously using open circuit spirometry. RPE was measured using the Borg scale at 5 and 10 minute during, and again immediately following the completion of testing. Resting oral temperature was the only variable to show a significant time of day effect (p <0.05). Oral temperature during the afternoon was higher than both morning and evening results by 0.76 degrees C and 0.09 degrees C respectively. Total work (KJ) and average power output (W) were recorded at their highest during the morning session reached a trough during the afternoon session, but these differences were not significant (P = 0.9972 respectively). The results obtained in this study indicate that while certain biological rhythms are present, they appear to have no effect on this type of cycling performance. Although athletic performance may be enhance by training programs that are compatible with an individuals body clock, the ability to perform and train at various times has an adaptive response which appears to over-ride these naturally inherent rhythms.
Yasuda J.N.et.al.\textsuperscript{21}. Studied the effect of exercise and circadian rhythm on blood coagulation and fibrinolysis. The purpose of this study was to compare blood coagulation and fibrinolytic response to exercise at different times of the day. Six regularly active men (21±1 years of age) took part in our experiments at 3:00 am, 9:00 am, 3:00 pm and 9 pm. After undergoing a respiratory function test, each subject performed maximal exercise on a bicycle ergo meter at each of the four times. Blood was collected before. Immediately after and one hour after exercise while the subject was seated. Each experiment was performed at a week intervals. The following were measured: Vital Capacity (VC), Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV 1.0), Peak Flow Rate (PEFR), Vo2 max, Prothrombin Time (PT), Active Partial Thrombin Time (APTT), Fibrinogen (Fbg), Anti-Thrombin-3 (AT-3), Protein C (PC), Plasminogen (10g), Tissue Type Plasminogen Activator (t-PA), Antiplasmin (anti-P1), Plasminogen Activator Inhibitor-1 (AAI-1), Fibrin Degradation Products (FDP) and D timer. Data were analyzed using a 2 way ANOVA with repeated measure. At 3:00pm, significant shortening of APTT was markedly shortened (125\%, P<0.01)

\textsuperscript{21} J.N.Yasuda."The Effect of Exercise and Circadian Rhythm on Blood Coagulation and Fibrinolysis", Medicine and Science in Sports and Exercise,1997;29:S-140
respectively. At 9:00 am and 9:00 pm. No statistically significant differences were seen in respiratory function tests Vo2 max at any of the time. These data suggest from the standpoint of coagulation and fibrinolysis, exercise is safer and more effective at 3:00 pm than as the other times.

Smith J.C.et.al.22 Studied circadian pacemakers evoked changes in Blood Pressure and Heart Rate in fit elderly men. It has been hypothesized that increase in Blood Pressure (BP) and Heart Rate (HR) during the early morning hours contribute to the high prevalence of myocardial infarctions (MIs) shortly after awakening. It is unclear if these BP and HR changes are consequences of behavioral and physiological events that are associated with the transition to wakefulness or if these Cardio Vascular (CV) changes are evoked by the suprachiasmatic nucleus (i.e. circadian pacemaker). To address this question =, 1- hr after and libatum sleep in the laboratory HR and BP were assessed every 20-men for 24-hrs under constant conditions (including continuous semi-recumbent wakefulness) in order to unmask indigenous circadian rhythm. Eight highly active (62.8±19.7min day-1 of moderately activity) and bit (VO2 peak = 38.2

±MKg-1min-1) elderly men (age = 64 ± 2 years) free from BP medication participated. A locally weighted regression algorithm was used to estimate the acrophase (peak) is nadir and amplitude (peak minus 24-hr mean) of the CD data expressed in both Military Time (MT) and Circadian Time (CT). The nadir of each participant’s rectal temperature under constant conditions served as the circadian phase marker (CT=0). The result showed large circadian amplitudes and similarly limited acrophases (at CT 4-5) for all three CV variables. It is concluded that ;( 1) Early morning increases in BP and HR are evoked by the circadian pacemakers, and (2) When expressed in circadian time, the acrophases of these parameters coincide with the time of day that most MIs occur

<table>
<thead>
<tr>
<th></th>
<th>24-hr mean ±SD</th>
<th>Nadir</th>
<th>Acrophase</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MT</td>
<td>CT</td>
<td>MT</td>
<td>CT</td>
</tr>
<tr>
<td>Systolic</td>
<td>116±3</td>
<td>01:00</td>
<td>00:00</td>
<td>14:00</td>
</tr>
<tr>
<td>Diastolic</td>
<td>76±2</td>
<td>01:00</td>
<td>00:00</td>
<td>07:00</td>
</tr>
<tr>
<td>Heart rate</td>
<td>56±2</td>
<td>00:00</td>
<td>18:00</td>
<td>09:00</td>
</tr>
</tbody>
</table>
Supported by a cybex research grant on exercise and human agency from the American College of Sports Medicine Foundation.

Krantz D.S., et.al.\textsuperscript{23} Studied that the morning peak in myocardial ischemia has been related to diurnal Variation in physical and mental activities and to postural changes upon awakening. This study assesses (1) the effects of exogenous activity triggers at different times of the day and (2) the contribution of an endogenous (i.e., activity- and posture-independent) circadian vulnerability for ambulatory ischemia. Sixty-three stable coronary artery disease patients underwent ambulatory ECG monitoring and completed a structured diary assessing physical and mental activities. During 25:19 hours of observation, a morning increase in ischemia coincided with increases in physical and mental activities, and an evening decrease in ischemia coincided with a decline in activities. During the morning, ischemic versus ischemia-free periods were more likely to occur with high levels of physical activity (P < .001). High physical activity triggered ischemia to a lesser but still significant extent (P < .05) in the afternoon but not in the evening (P = NS). High levels of mental activity triggered ischemia significantly during the morning (P < .04)

and evening (P < .04) but not in the afternoon. When a residualized score procedure was used to correct ischemic time for each patient's simultaneously measured activities, for hourly heart rates, or for activity-related heart rate fluctuations, the circadian variation in ischemia was still observed (P < .001), with a peak at 6 AM. A significant increase in ischemia occurred immediately after awakening (P < .05), but activity-adjusted increases in morning ischemia persisted (P < .05) for 2 hours after awakening. Exogenous factors (physical and mental activities) are most potent as triggers of ischemia during the morning hours, and the postural change after awakening contributes to the morning increase in ischemia. There is also evidence for an endogenous, activity-independent circadian influence on ischemic susceptibility that is independent of exogenous factors and that sustains the increase in ischemia upon awakening.

Reilly T., Brooks G.A.²⁴ This study examined the existence of circadian rhythms in rectal temperature (Tr) and selected skin temperatures at rest and during light (82 W) and medium (147 W) exercise on a cycle ergometer. Each intensity was sustained for 5 min and then followed by a graded exercise test to exhaustion. The Tr and

skin temperatures were also measured on cessation of exercise and 4 min post-exercise. Fifteen males participated, measurements covering six interspersed times of day. The mean exercise time to exhaustion of 19.83 min was independent of the time of day and caused a constant rise of 0.7 degree C in Tr. Significant rhythms were observed in Tr, Tc (chest), and Ta (arm) under all conditions: findings for Tl (leg) were no significant at maximal exercise and post-exercise (P >0.05). The crest time for Tl had a significant lead over that of Tr and the other skin sites which were in phase concordance, mean difference in crest times being 4.73 h at rest and 4.42 h during sub-maximal exercise. The results demonstrated constancy with time of day in the thermal load imposed by fixed exercise. This was reinforced when mean skin and mean body temperatures were computed. The general pattern did not apply to the exercised limb, the pre-exercise rhythm disappearing after 10 min exercise. Differential heat conductances according to skin sites are implicated in the phase differences between the leg and the other temperature sites.

Cohen C.J., et.al. Conducted a study on circadian variation of the respiratory exchange ratio during sub-maximal treadmill exercise.

---

Physiological response to exercise are thought to be affected by the time of day at which that exercise is performance based on the circadian variation of many physiological function as demonstrated in the literature (Hill and Zammer, 1994; Hill et al., 1989).

The purpose of the study was to determine whether a circadian variation appeared in RER archived during moderately fit young adults, with a documented history of 4-6 months of run training. VO2 peak was determined utilizing a progressive, incremental treadmill test; a running pace equivalent to 75% of measures VO2 peak was then calculated. Each subject performed a 20 minute run at this level of exercise intensity at 3 different times of the day: 0900, 1500 & 2100 hours, the order of testing was randomly assigned with a minimum of 48 hours separating each exercise test. Duty were analyzed using RER according to the time of day, the results shows no statistically significant differences across the 3 times of day for RER. The results of this study therefore, indicate the circadian variation, while present to some degree, did not have an impact on this specific physiological measurement of RER.
Rodahl, et al\textsuperscript{26} conducted a study on circadian rhythms in power output on a swim bench. Circadian variation in power output (as performed on biokinetic swim bench) and its relation to circadian rhythms in body temperature and subjective alertness were measured in 14 competent swimmers at six equidistant times (starting at 2:00hr) of the day. Peak and mean power on 30s test were noted. Subjective scale responses for alertness and pre exercise rectal temperatures were recorded.

Distinctive circadian rhythms for pulse rate, rectal temperature, alertness, and both power measures were exhibited. The general time for the peak values in the rhythm was 14% for mean power and 11% for peak power. It was suggested that the amplitude that the circadian rhythms increases with the complexity of motor task are affected because of the size of the values obtained. Complex activities to a greater degree by circadian rhythms that are simple activities.

The circadian rhythm in power output on a swim bench was closely related to the rhythm for body temperature and alertness. The existence of these rhythms should be taken into account when planning strength and power training stimuli.

Another implication of these findings is that comparative performances and test results must be gathered at the same time of day. Otherwise, test differences are so many of the could solely be the results of circadian predispositions.

Fraser J., et al.\textsuperscript{27} Observed the effect of sleep and circadian cycle on sleep period energy expenditure. Energy expenditure is lower during sleep than relaxed wakefulness. However, there is disagreement on particular metabolic changes that produce the difference. The present study assesses the contribution of sleep, circadian cycle and the specific dynamic action effect of evening meal of the sleep period fall in metabolic rate. Five subjects were tested for a total of 9 nights under three conditions in a repeated measure design. Subjects were confined to go to sleep 0.3 or 6 hrs after their usual time for lights out. O2 consumption was measured for all condition for the 0.5 h before and after each of the times for light out and then throughout the sleep period after lights out. The result demonstrated that changes in energy expenditure during the sleep period are a function of both sleep and circadian cycle. In this study the contribution of 2 components was extremely equal. However, the

effect of sleep was rapid asymptotic within 15 min of sleep onset. Whereas that of circadian cycle was constant over the assessment period.

Brisswalter J. et.al. To investigate the effects of both an Active Warm-Up (AWU) and the diurnal increase in body temperature on Muscular Power. Eight male subjects performed maximal cycling sprints in the morning (7:00-9:00 a.m.) and afternoon (5:00-7:00 p.m.) either after an AWU or in a control condition. The AWU consisted of 12 min of pedaling at 50% of & OV0312; O2 max inter-spersed with three brief accelerations of 5 s. Rectal Temperature, Maximal Force developed during the cycling sprint, and Muscular Power were higher in the afternoon than in the morning (P<0.05). Rectal Temperature, calculated Muscular Temperature, and Muscular Power were higher after AWU than in control condition (P<0.05). The beneficial effect of an AWU can be combined with that of the diurnal increase in central temperature to improve Muscular Power.

Reilly T. Atkinson G., et.al. Studied that variables associated with physical activity show circadian rhythms in resting subjects;

these rhythms have both exogenous (due to the individual's lifestyle and environment) and endogenous (due to the "body clock") components. During exercise, many of the rhythms persist, even though some show decreasing amplitude with increasing severity of exercise. Whilst the value of physical fitness is not disputed (for elite athletes, for individuals who just want to be physically fit, or for patients undertaking physical rehabilitation regimens), there are certain times of the day when special care is needed. These times are soon after waking--when there is the possibility of an increased risk of cardiovascular morbidity and damage to the spine--and late in the day--when there is an increased risk of respiratory difficulties. Since physical exercise is inextricably linked with thermoregulation, there are special considerations to bear in mind when exercise takes place in cold or hot environments. Further, due to the effects of the body clock, exercise and activity during night work and after time-zone transitions presents problems peculiar to these circumstances. In addition, the menstrual cycle affects physical performance, and these circadian rhythms interact with the circadian ones. Bearing in mind these factors, advice that is based upon knowledge of circadian and circadian rhythms can be given to all those contemplating physical activity. Chronobiologically, there is advantage in undertaking
physical activity programmes towards the middle of the waking day
and not at times when a sleep or nap has just been taken.

Racinias, et al.\textsuperscript{30} conducted a study on effect of an acute hot
and dry exposure in moderately warm and humid environment on
muscle performance at different times of day. This study investigated
whether 30 min of acute hot exposure has an additional passive warm-
up effect for the improvement in muscle performance in a moderately
warm and humid environment. We also sought to determine whether
this effect is dependent on the diurnal variation in body temperature.
mass: 69.3 [± 10] kg were tested (CMJ, cycling sprints, and isokinetic
contractions of the knee flexors and extensors) in a moderately warm
and without acute heat exposure (30 min of rest in a sauna at 76 [± 2]
degrees C and 27 [± 1] % rh, both in the morning (07:00 – 09:00 h)
and in the evening (17:00 – 19:00 h). Our results indicated a
significant effect of both time of day and acute heat exposure on leg
skin temperature (p <0.05) but failed to show any effect of time of
day or acute heat exposure on the various evaluated parameters (CMJ:

\textsuperscript{30} S.Racinias et al., "Effect of an Acute Hot and Dry Exposure in Moderately Warm and Humid
Environment on Muscle Performance at Different Times of Day", \textit{International Journal of
Sports Medicine}, 2006; 27 (1): 49-54
speed, force, power, and height; cycling power: over a half pedal revolution and a total pedal revolution; isokinetic torque: knee extensor and flexor muscles at 4.19 rad × s (-1)3.14 rad × s (-1), 2.09 rad × s (-1), and 1.05 rad × s (-1). In conclusion, our data suggest that 30 minutes of acute hot exposure does not have any passive warm-up effect in a moderately warm and humid environment. Furthermore, the diurnal variation in body temperature has no passive warm up effect in a moderately warm and humid or in an extremely hot

Reilly T., et.al.\textsuperscript{31} Examined the isolated and combined effects of time of day and menstrual cycle phase on the determination of lactate threshold (T lac) and blood lactate concentration. Eleven endurance trained female athletes (mean age 32.4±6.9 years) were tested at 06:00 and 18:00h and at two phases of menstrual cycle, the midfollicular phase and midluteal phase. Capillary blood (25ul) was obtained from the tip of the toe at rest, and during the lasts 30s of a continuous multistage, 3 min incremental protocol on the concept 2 ergo meter. To determine T-lac, a curve fitting procedure (D max method), a visual method (Tlac-vis), and the fixed blood lactate

concentration of 4.0 mmolL (Tlac-4mM) were used, ventilatory threshold (T vent) was also determined.

In the midluteal phase of the menstrual cycle, Tlac -4mM occurred at a significantly higher exercise intensity heart rate, and oxygen consumption than it did in the midfollicular phase. Blood lactate concentration at T vent and at Tlac using the Dmax method was significantly lower in the midluteal phase. No significant interaction effects (menstrual cycle × time of day) were observed for any of the methods used to determine T-lac or for values of blood lactate concentration at rest and maximum.

The normal circadian rhythm in exercise performance may be altered by the habitual timing of training. We have investigated if morning time trial performance is affected by the time at which moderate exercise is performed on the previous day. Eight male cyclists undertook two separate exercise sessions of sub-maximal cycle ergometry (60% V.O2peak for 30 min) at 07:00 h and 12:00 h the day before a 16.1-km time trial at 07:00 h. Heart Rate, Power Output, Ratings of Perceived Exertion, and Rectal Temperature were measured at rest and every 5 min in the pre-time trial exercises, and every 1.61 km during the time trial. Blood samples were taken at rest
and immediately after the time trial for the measurement of lactate concentration. The time trial performed the day after the 07:00 h sub-maximal exercise was completed in $1672\pm135$ s, compared to $1706\pm159$ s for the time trial performed the day after the noon pre-time trial exercise ($p=0.027$). The time trial after exercise the previous morning was associated with higher work-rates ($p=0.031$), a higher net lactate accumulation after the time trial ($p=0.018$), and a trend for higher Heart Rates ($p=0.093$) compared to the time trial after exercise the previous noon. These findings suggest that cycling performance in an early morning time trial is improved if an athlete participates in early-morning rather than noontime moderate exercise the day before. This finding cannot be attributed to the physiological responses to the exercise on the pre-time trial day or to environmental factors. It is suggested that it might partly reflect an advantage gained by performing exercise in the day(s) immediately beforehand at the same time as the competition.

Edwards B.J., et.al.\textsuperscript{32} Studied that in badminton, the short doubles serve requires accuracy, whereas the long singles serve also requires power. The present study investigated if there are time-of-day

effects for these two types of serve. Eight male badminton players completed two familiarization sessions before being tested at 08:00, 14:00 and 20:00 hours, the session times being counterbalanced. At each session, subjects performed ten warm-up serves, followed by ten short and ten long test serves. A 1 m2 yellow grid was placed at the front of the recipient's service box (short serve) or at the back of the court along the centre line (long serve). Subjects scored 'hits' with their serves by putting the shuttle in the grid as close as possible to one corner of the target grids. Accuracy was assessed by calculating the average Radial Error (RE) of the serves, and consistency by calculating the standard deviation of the RE. Data were analyzed by ANOVA. There was a time of day effect for temperature (p < 0.0005) and a trend in this for grip strength (p = 0.052). The accuracy of the 'hits' was highest at 14:00 hours (p < 0.05) and the short serve showed greater accuracy than the long serve (p < 0.0005). There was a significant effect of serve number with the short serve, subjects getting more accurate with later serves (p = 0.036). No significant variation in consistency was found (p > 0.05). In summary, the lack of agreement in profiles for temperature and the accuracies of long and short service suggest that some factor(s) that deteriorate during the course of the
time spent awake might be involved, in addition to body temperature, in determining accuracy in the tasks measured.

Nicolas A., et al. The aim of this study was to examine the Time-of-Day (TOD) effects in myoelectric and mechanical properties of muscle during a maximal and prolonged isokinetic exercise. Twelve male subjects were asked to perform 50 Maximal Voluntary Contractions (MVC) of the knee extensor muscles at a constant angular velocity of 2.09 rad. Sec (-1), at 06:00 and 18:00 h. Torque and Electromyographic (EMG) parameters were recorded for each contraction, and the ratio between these values was calculated to evaluate variations of the Neuromuscular Efficiency (NME) with fatigue and with TOD. The results indicated that maximal torque values (T(45)Max) were significantly higher (7.73%) in the evening than in the morning (p<0.003). The diurnal variation in torque decrease was used to define two phases. During the first phase (1st to the 26th repetition), torque values decreased fast and values were higher in the evening than in the morning, and during the second phase (27th to the 50th repetition), torque decreased slightly and reached a floor value that appeared constant with TOD. The EMG

parameters (Root Mean Square; RMS) were modified with fatigue, but were not TOD dependent. The NME decrease significantly with fatigue, showing that peripheral factors were mainly involved in the torque decrease. Furthermore, NME decrease was greater at 18:00 than at 06:00 h for the vastus medialis (p<0.05) and the vastus lateralis muscles (p<0.002), and this occurred during the first fatigue phase of the exercise. In conclusion, the diurnal variation of the muscle fatigue observed during a maximal and prolonged isokinetic exercise seems to reflect on the muscle, with a greater contractile capacity but a higher fatigability in the evening compared to the morning.

Racinais S.et.al.\textsuperscript{34} Investigated the effect of time-of-day on both maximal sprint power and Repeated-Sprint Ability (RSA). Nine volunteers (22±4 yrs) performed a RSA test both in the morning (07:00 to 09:00 h) and evening (17:00 to 19:00 h) on different days in a random order. The RSA cycle test consisted of five, 6 sec maximal sprints interspersed by 24 sec of passive recovery. Both blood lactate concentration and heart rate were higher in the evening than morning RSA (lactate values post exercise: 13±3 versus 11±3 Mmol/L (-1),

p<0.05). The peak power developed during the first sprint was higher in the evening than morning (958±112 vs. 915±133 W, p<0.05), but this difference was not apparent in subsequent sprints, leading to a higher power decrement across the 5x6 sec test in the evening (11±2 vs. 7±3%, p<0.05). Both the total work during the RSA cycle test and the power developed during bouts 2 to 5 failed to be influenced by time-of-day. This suggests that the beneficial effect of time-of-day may be limited to a single expression of muscular power and fails to advantage performance during repeated sprints.

Racinais S.et.al.35 investigated the effects of environmental temperature and the diurnal increase body temperature on muscle contractile processes. 11 males subjects performed maximal and sub-maximal isometric contractions of the knee extensors with recording of the electromyographic activity in four different conditions (morning/neutral, morning/moderately warm and humid, afternoon/neutral, and afternoon /moderately warm and humid). The morning experiments were conducted between 0700 and 1900 h, and the afternoon experiments were conducted between 0500 and 0700 h. the mean laboratory temperatures and humidity were 20.5 (±1)

degrees C + 67 (±4%) and 29.5 (±0.8) degrees C + 74 (±10%) for the
neutral and moderately warm and humid conditions, respectively.
Results showed a significant diurnal increase in both rectal and skin
temperatures whatever the environmental conditions and an increase
in the skin temperature after a 60 min moderately warm exposure. The
major findings of this study were an interaction effect of time of day
and environmental conditions on the force/electromyographic activity
ratio. That suggests that skeletal muscle contractibility was differently
increased by the passive warm up effect of a moderately warm
exposure, depending on the diurnal variation in body temperature.
This conclusion is supported by an increase in force in the morning
only after a 60 min warm exposure (+19%) and in a neutral
environment only with the diurnal increase in body temperature (+12%).

Arnett M.G.et.al. Examined the effect of a morning and
afternoon practice schedule on morning and afternoon swim
performance. Participants for this investigation included 6 men and 4
women competitive swimmers (mean age = 15.3 +/- 0.95 years).
Training involved 4 months of a morning and afternoon practice

schedule, volume, relative intensity, and frequency during training were the same for all swimmers. Participants swam 4 times per week in the morning and 5 times per week in the afternoon. Outcomes were measured initially and after the 4-month morning and afternoon practice schedule in both the morning and afternoon. Prior to entering the water to swim a 91.44m freestyle stroke, each swimmers body temperature was taken from the ear. Immediately following the swim performance, participants were asked to Rate their Perceived Exertion (RPE) based on Borg's CR – 10 rating scale. The order of the test administration for the time of day was balanced. Testing was conducted at the same time of day as the training sessions. Each swimmer completed 1 test condition per day. Diurnal variation in body temperature was not affected by a morning and afternoon practice schedule \((p = 0.0001)\). A diurnal trend appeared for RPE following a morning and an afternoon practice schedule, but the trend was opposite that reported for body temperature \((p = 0.089)\). However, same time differences witnessed between the initial morning and afternoon measurement \((p = 0.017)\) decreased for participants involved in a morning and afternoon practice schedule \((p = 0.017)\) decreased for participants involved in a morning and afternoon practice schedule \((p = 0.069)\).
Hue O., et.al.\textsuperscript{37} Evaluated the influence of a neural vs. a moderately warm environment on the diurnal variation in muscular power. Twelve male subjects [27.0 (±4) years] performed two different jump tests [A Squat Jump (SJ) and a Counter-Movement Jump (CMJ) and a brief maximal sprint on cycle ergometer (CS) in four different conditions (morning / neutral, morning/moderately warm and humid)]. The morning experiments were conducted between 07:00 and 09:00 h. The mean laboratory temperatures and humidity were 20 (±1) degrees C, 70 (±5) % and 29 (±1) degrees C, 57 (±4) % for the neural and moderately warm and humid conditions, respectively. Rectal temperature and leg skin temperature were significantly dependent on both time of day and ambient temperature. An interaction effect (p < 0.05) was noted between time of day and ambient temperature for the power developed for the CMJ, the SJ and half of a pedal revolution during the cycling sprint. In summary,

1. The same subjects were influenced by time of day differently, depending on the ambient temperature during testing.

2. Time of day affected muscular performance only in the neutral conditions.

3. The moderately warm and humid conditions blunted the diurnal variation in muscular performance, and

4. The effect of the ambient temperature was dependent on time of day.

Falagaairrette G., et al. studied the effects of recovery duration (2-3 s, 15 s, 30 s, 1 min, and 2 min) and time of day (9 a.m., and 2 p.m., and 6 p.m.) on sprint performance were studied in 9 subjects using a cycle ergo meter. The peak power (peak) and the total work performed (W) were determined from changes in instantaneous power, taking into account the inertia of the flywheel. A decrease in P peak and W was observed after 15 s and 2-3 s recovery (p < 0.001). A logarithm relationship peak (% peak of the first sprint) and the duration of the recovery (half-time = 14.3; SD = 7.6). Data indicated there was significant effect of time of day on Ppeak and W, regardless of the duration of recovery. The recovery processes occurred in a very short time and did not see to be affected by biological rhythms.
Aoki K., Kondo N, et.al.\textsuperscript{39} To investigate the influence of non-thermal factors in the time-of-day effect on the sweating response to maintained static exercise, eight healthy male subjects performed handgrip exercise at 20\%, 35\% and 50\% maximal voluntary contraction (MVC) for 60 s at 0600 hours (morning) and at 1800 hours (evening). Oesophageal temperature \((T(\text{oes}))\) before the experiment showed a diurnal rhythm [mean (SEM)] [36.3 (0.1) (morning) compared to 36.8 (0.1) degrees C (evening), \(P<0.01\)]. Experiments were conducted with subjects in a state of mild hyperthermia during which the mean skin temperature \((T(\text{SK}))\) was kept constant at 35.5-36.5 degrees C using a water-per fused suit to activate sudomotor responses. The \(T(\text{oes})\) and mean \(T(\text{sk})\) remained stable during the pre-exercise, handgrip exercise and recovery periods. The response in sweating rate (DeltaSR) on the chest and forearm to handgrip exercise increased significantly with increasing exercise intensity in both the morning and evening test (\(P<0.05\)). The DeltaSR on the palm did not change significantly with increasing exercise intensity in the morning test (\(P>0.1\)). During handgrip exercise at 50\% MVC only, DeltaSR on the chest, forearm and palm in the evening was significantly higher.

than in the morning (P<0.05). On the other hand, mean arterial blood pressure and the rating of perceived exertion during 50% MVC handgrip exercise were not significantly different between the morning and evening (P>0.1). These results indicate the presence of a time-of-day effect on non thermal control of the sweating response to isometric handgrip exercise, and that this effect is dependent on exercise intensity.

Aldemir H., et al.\textsuperscript{40} Conducted study on Twelve healthy male subjects each undertook two bouts of moderate exercise (70% VO2max for 30 minutes) in the morning (08:00) and late afternoon (18:00) at least 4 days apart. Measurements were made of heart rate, core (rectal) temperature, sternum skin temperature, and forearm skin blood flow during baseline conditions, during the bout of exercise, and throughout a 30-minute recovery period. Comparisons were made of the changes of heart rate, temperature, and skin blood flow produced by the exercise at the two times of day. Student t tests indicated that baseline values for core temperature (37.15 degrees C ± 0.06 degrees C vs. 36.77 degrees C ± 0.06 degrees C) and sternum temperature (33.60 degrees C ± 0.29 degrees C vs. 32.70 degrees C ± 0.38 degrees C).

\textsuperscript{40} H. Aldemir and G. Atkinson, “A Comparison of The Immediate Effects of Moderate Exercise in the Late Morning and Late Afternoon on Core temperature and Cutaneous Thermoregulatory Mechanisms”, Chronobiology International, 2000;17(2):197-207.
C) were significantly ($p < .05$) higher in the late afternoon than the early morning. Two-way analysis of variance (ANOVA) indicated that the increases in core and sternum temperatures during exercise were significantly less ($p = .0039$ and .0421, respectively) during the afternoon bout of exercise compared with the morning, even though the work loads, as determined by changes in Heart Rate, were not significantly different ($p = .798$) at the two times of testing. There were also tendencies for resting forearm skin blood flow to be higher in the afternoon than in the morning and for exercise to produce a more rapid rise in this variable in the afternoon. The possible mechanisms producing these responses to exercise are discussed in terms of those that are responsible for the normal circadian rhythm of core temperature. It is concluded that the body's ability to remove a heat load is less in the early morning, when the circadian system is in a "heat gain" mode, than in the late afternoon, when heat gain and "heat loss" modes are balanced more evenly.

Degroot D., et al. Examined how time of day affects shivering and peripheral heat loss during cold-water immersion (CWL). It was hypothesized that the physiological response to CWI (increased
metabolic heat production (M) decreased Peripheral Heat Flow (HF) and mean skin temperature [Tsk] would differ at 0700h compared to 1500h due to the lower initial core temperature at 700h, associated with the circadian rhythm. Nine men were immersed (2h) to the shoulders in 20 degree C in two separate days randomized once at 0700h and once at 1500h. No differences (P <0.05) between 0700h and 1500h immersion were observed for M (~150Wm-2), HF (~250Wm-2)&Tsk (~21 degree C). No differences were observed between 0700 & 150h CWI in the relationship between mean body temperature and M indicating that the threshold and sensitivity of shivering was unaffected by time of day. Rectal temperature (Tre) was higher (P <0.05) before (Delta =0.4 degree C) & throughout CWI at 1500h vs. 700h. The change in Tre was greater at 1500 (-1.4degree C) vs. 070h (-1.2 degree C) likely due to the higher Tre-Tsk gradient (~0.3 degree C) at 1500h. These data suggest that control of shivering and peripheral HF are similar at 0700h and 1500h during CWI and raise the possibility that CWI may pose a greater risk of hypothermic in the early morning than late afternoon due to a lower initial core temperature.
Aoki K., et.al. Studied the effect of time of day on sweating responses to sustained static exercise. To investigate the effect of time of day on sweating response to a sustained state exercise (non thermal sweating response), 8 male subjects in a state of mild hyperthermia performed on isometric handgrip exercise at 20, 35 and 50% Maximal Voluntary Contraction (MVC) for 60 seconds. The experiments were conducted at 0400-0800 (morning) and 160-2000 hours (evening). The order was randomly assigned prior to the isometric handgrip exercise. The whole body skin temperature of subject was warmed using a suit perused with water at 38-degree C. the esophageal and mean skin temperature did not change significantly during the isometric handgrip exercise cut any intensity. During the isometric handgrip exercise in the morning and evening, the increase in local sweating rate (delta SR) on the chest and forearm, heart rate mean arterial pressure and rating of perceives exertion increased significantly with a rise in exercise intensity (P <0.05) on the other hand in the morning delta SR on the palm did not show a significant increase with a rise in intensity. During the 20 and 35 % MVC handgrip exercise. Delta SR on the chest and forearm did not show a

time of day effect, whereas during 50% MVC handgrip exercise, these parameters were significantly higher in the evening than in the morning (P <0.05). These results suggest that the time of day effect on non-thermal sweating response without modulation by a change of internal and skin temperature only occurs with a high intensity.

Guir H.G., et.al\textsuperscript{43} Studied the effects of time period of day on metabolic cost of maximal exercise performed on + and − slopes. To examine the effects of time period of day on metabolic changes during and after the maximal cycling exercise performed on positive (+SI) and negative (-SI) slopes, 15 moderately active male subjects aged 19-26, volunteered for this study. The subjects performed maximal cycling exercise at the +SI (+ 10%) and − SI (-0%) for 5 min in the morning (08:30-10.00am) and in the afternoon (15:30-18:00pm). Subject’s Oxygen Consumption, Energy Expenditure (En.Ex), Respiratory Change Ratio (RER) during the following exercise (for 30 minutes) and post exercise-blood lactate (at the third min) were measured. Paired observation t-test and MANOVA were used to analyze the data. While evaluated parameters did not show statistically difference between AM and PM for +51 exercise, oxygen

consumption for the first 10 min and for 30 min were greater (P<0.05) at PM values at AM for merely -S1 exercise. Post exercise EnEx was greater (P<0.05) at PM Compared AM for the first and third 10 min periods in +S1 exercise. The findings indicated that

1. Metabolic cost of maximal exercise performed on +S1 do not show AM –PM differences.

2. Metabolic cost of maximal exercise performed on -S1 is greater at AM compared to PM.

Koltyan K.F.et.al. Studied the effect of time of day and gender on pain perception and selected psychobiological responses. The literature regarding whether or not there are gender and diurnal differences in pain perception is equivocal. The purpose of this study was to examine the influence of gender and time of day on pain threshold (PT) and pain ratings (PR). A secondary purpose was to measure selected psychological (STAI, POMS) and physiological (SBP, DBP, HR, Temp) responses. Pressure (3000 gm force) was applied to the middle digit of the left forefinger for 2- min with the forefinger Barber pain stimulator. Twenty-nine volunteers ( women =14; men =15) completed 2 randomly assigned sessions between

---

6:00-8:00 in the AM & PM. STAI, POMS & TEMP were assessed before the stimulus, while BP & HR were assessed before and following the pressure stimulus. Data were analyzed with a 2×2 ANOVA. Results indicated that men had significantly higher (P<0.05) pain threshold than women however, there was not a significant time of a day effect (P <0.05). PR & HR were found to be significantly higher (P<0.05) in women in comparison to men significant time of day effect (P<0.05) were found for TEMP, SBP and vigor. It is concluded that PT did not differ in the AM and PM, and that men had higher PT than women.

Atkinson G., Reilly T. 45 This study was designed to examine the effects of age and time of day on work rates during prolonged, self-paced exercise. Eight young (19-25 years of age) and eight old (48-62 years of age) endurance athletes volunteered for the study. At two times of day (07:00 and 17:00 h), subjects were asked to pedal on a Monark cycle ergometer (Varberg, Sweden) at a self-chosen exercise intensity that they believed they could sustain for exactly 80 min. This self-chosen Work Rate, Rectal Temperature, Skin Temperature (chest, arm, and lower leg), Oxygen Consumption

(VO2), Expired Carbon Dioxide (VCO2), Minute Ventilation (VE), Heart Rate, and Perceived Exertion (RPE) were recorded every 10 min during the exercise. Pre-exercise resting measures of rectal temperature, VO2), and VE were less affected by the time of day in the older group than were those in the young subjects (p<0.05). In the morning, rectal temperature was 0.3 degrees C higher in the older subjects than in the young adults. Diurnal variation in mean work rate over the 80-min exercise period was not evident in the old group (p>0.10) but amounted to 10 W in the young group (p<0.05). Older subjects chose work rates 5.4 W lower than did the young subjects in the morning test session (p>0.10). In the afternoon, age differences in work rate amounted to 14.3 W (p<0.05). For all subjects, work rates remained relatively constant throughout the exercise period in the morning. In the afternoon, subjects chose high work rates within the first 40 min of exercise, after which work rate decreased sharply to values similar to those recorded in the morning (p<0.01). These changes were mirrored closely by changes in (VO2) and VCO2). Perceived exertion increased linearly throughout exercise, irrespective of age or time of day. These results suggest that, in young adults, the mean work rate over 80 min of exercise is higher in the afternoon than in the morning, although the work rate decreased sharply toward the
end of the afternoon exercise. In agreement with studies reporting age-related increases in "morning ness," age differences in work rate appeared to be least when exercise was performed in the morning.

Torii M. et al.\textsuperscript{46} The purpose of this study was to compare the thermoregulatory responses during exercise in the morning rise (0900 h) and evening fall phases (2000 h) in circadian variation of body temperature. Five healthy volunteers performed bicycle exercises at 30% and 60% of maximal aerobic power (VO\textsubscript{2max}) at 26 degrees C with a relative humidity of 50%. Whole-body Sweat Rate (SR), Rectal (Tre), Mean Skin (Tsk) and Mean Body (Tb) Temperature, Pulmonary Ventilation (VE), Oxygen Uptake (VO\textsubscript{2}), and Carbon Dioxide Output (VCO\textsubscript{2}) and Heart Rate (HR) were measured during the experimental period. SR during exercise at 30% VO\textsubscript{2max} was significantly higher at 2000 h than at 0900 h. However, the circadian variation of SR during exercise was not observed at 60% VO\textsubscript{2max}. At the two experimental times, there were also no significant differences in VO\textsubscript{2}, VCO\textsubscript{2}, VE and Tsk in both workloads. In HR, Tb and Tre circadian effects were demonstrated as well as in workload levels. As Tb was plotted against SR during exercise, positive correlations were

observed. The data showed that there was a parallel shift in the SR to Tb relationship during exercise in the morning and evening. This rightward shift indicated that there was an increased Tb threshold for the onset of sweating in the evening. Resting Tb at 2000 h was significantly higher when compared with Tb at 0900 h. The present results suggest that the circadian influence on the thermoregulatory resp Liferman, et al\textsuperscript{47} measured morning and afternoon responses to anaerobic work in college women before and after a training program that was performed at only one time a day. Time to exhaustion and anaerobic capacity were greatest at the time of training. Either training at a particular time of day results in greater adaptations at the time of day, or it influences the phase of the circadian rhythm response to exercise. The time of day when training is performed affects performance at that time. In serious athletes who compete at specific times in the day/night, the last phase of training should be performed at the same times as the anticipated competitive efforts. Response to exercise may be evident only at low workloads.

Linda, et al\textsuperscript{48} investigated to determine:

1. Whether the fibrinolytic responses to acute, sub-maximal exercise were best related to intensity, duration, or total caloric expenditure; and

2. Whether the time of day exercise is performed affects the fibrinolytic response.

Twelve physically active men (mean age = 34.8±4.0yr) performed four 30 min exercise sessions: 50% VO2 max, a.m. and p.m., 80% VO2 max, a.m. and p.m. Blood samples were analyzed for Tissue Plasminogen Activator (PAI-1) activity. Data were analyzed using a three-way ANOVA with repeated measures. TPA activity: pre-exercise TPA did not differ among the four sessions. TPA increased with exercise in all sessions except the 50% a.m. sessions. Exercise at 80% increased TPA more than 50% (P <0.001) and evening sessions increased TPA more than morning sessions (P <0.05). PAI-1 activity; pre-exercise PAI-1 activity was higher during the morning than evening and significantly decreased with exercise in all sessions except the 50% p.m. session. It was concluded that changes in fibrinolytic activity appear to be influence primarily by exercise intensity rather than duration or total caloric expenditure.
Additionally, time of day of exercise performance significantly influenced fibrinolytic activity.

O'Connor P. and Davis J. et al\textsuperscript{49} conducted study to determine whether selected psychobiologic responses to running exercise vary as a function of the time of day at which exercise is performed. Twelve adult males completed four bouts of randomly assigned, submaximal exercise (20-min runs at 70\% VO\textsubscript{2}max) at 0800, 1200, 1600 and 2000 h. Since selected personality traits have previously been shown to influence circadian rhythms, personality assessments (i.e., Eysenck Personality Questionnaire, EPQ; Morningness-Eveningness Questionnaire, MEQ; Spielberger's State-Trait Anger Expression Inventory, STAIX; and State-Trait Anxiety Inventory, STAI) were made during the initial testing session. The group studied scored within the normal range on the traits assessed by the EPQ, STAIX, and STAI. Also, subjects were not able to be classified as either morning or evening types based on MEQ scores. Ten minutes before as well as 10 and 20 min following the exercise bouts, state anxiety, state anger, blood pressure, and heart rate were assessed. Multivariate ANOVAs (four time of day conditions x three trials) revealed

significant main effects for the trial factor for state anxiety, state anger, heart rate, and systolic blood pressure. State anxiety, state anger, and systolic blood pressure were found to be reduced at both the 10 and 20 min post-exercise assessment periods when compared with pre-exercise levels. ANOVAs performed on the difference scores showed that the mood improvements and cardiovascular changes were independent of the time of day that exercise was performed, and these findings were confirmed by ANCOVAs, which adjusted for differences in initial values across the four times of day conditions.