

# **INFLUENCE OF CIRCADIAN RHYTHM ON THE PHYSICAL AND MENTAL PERFORMANCE**

A Thesis

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# TABLE OF CONTENTS

|  |     |
|--|-----|
| ACKNOWLEDGEMENTS .....   | ii  |
| LIST OF TABLES .....   | v   |
| LIST OF FIGURES .....  | vi  |
| ABSTRACT .....   | vii |
| CHAPTER 1: INTRODUCTION .....  | 1   |
| 1.1 Problem Definition .....   | 3   |
| 1.2 Objectives .....   | 3   |
| CHAPTER 2: LITERATURE REVIEW .....   | 5   |
| 2.1 Affect of Circadian Rhythm on Various Bodily Functions and Performance ..... | 5   |
| 2.1.1 Circadian Phase Shift and Neurobehavioral/Cognitive Functioning .....      | 5   |
| 2.1.2 Circadian Rhythm and Temperature .....                                     | 9   |
| 2.1.3 Circadian Rhythm and Sleep-Wake Cycle .....                                | 13  |
| 2.1.4 Disturbances in Circadian Rhythm Pattern .....                             | 15  |
| 2.2 Findings of Literature Review .....  | 16  |
| CHAPTER 3: METHODOLOGY .....   | 17  |
| 3.1 Procedure .....  | 17  |
| 3.1.1 Participants .....   | 17  |
| 3.1.2 Equipment .....  | 17  |
| 3.1.3 Data Acquisition .....   | 18  |
| 3.1.4 Physical Strength .....  | 18  |
| 3.1.5 Mental Strength .....  | 20  |
| 3.2 Lunar Cycle and Performance .....  | 21  |
| CHAPTER 4: RESULTS .....   | 22  |
| 4.1 Data Interpretation .....  | 22  |
| 4.1.1 Temperature .....  | 22  |
| 4.1.2 Physical Strength .....  | 23  |
| 4.1.3 Mental Performance .....   | 23  |
| 4.1.4 Lunar Cycle and Performance .....  | 23  |
| 4.2 Statistical Analysis .....   | 24  |
| 4.2.1 Hypothesis 1 .....   | 24  |
| 4.2.2 Hypothesis 2 .....   | 27  |
| 4.2.3 Hypothesis 3 .....   | 28  |
| 4.2.4 Hypothesis 4 .....   | 29  |
| CHAPTER 5: DISCUSSIONS .....   | 30  |
| 5.1 Discussion of the Experiment .....   | 30  |

|  |   |    |
|--|---|----|
| 5.1.1  | Effect of Temperature Circadian Rhythm on Performance .....                         | 30 |
| 5.1.2  | Exhibition of a Common Circadian Rhythm Pattern .....                               | 32 |
| 5.1.3  | Effect of Temperature Circadian Rhythm on Performance in<br>Males and Females ..... | 33 |
| 5.1.4  | Impact of Lunar Cycle on Performance .....  | 34 |
| CHAPTER 6: CONCLUSION AND RECOMMENDATIONS .....  |   | 35 |
| 6.1  | Synopsis .....  | 35 |
| 6.2  | Conclusion .....  | 35 |
| 6.3  | Future Recommendations .....  | 36 |
| REFERENCES .....   |   | 38 |
| APPENDIX-A: CONSENT FORM .....   |   | 41 |
| APPENDIX-B: MENTAL PERFORMANCE TESTS GIVEN AT LOW AND HIGH<br>TEMPERATURES .....                 |   | 43 |
| APPENDIX-C: AVERAGE HOURLY TEMPERATURE FOR INDIVIDUAL<br>PARTICIPANTS OVER A 10-DAY PERIOD ..... |   | 45 |
| VITA .....   |   | 55 |

## LIST OF TABLES

|   |    |
|---|----|
| Table 1: Suduko Puzzle .....  | 20 |
| Table 2: Average Oral Temperature of All the Participants over a 10-Day Period.....                                     | 22 |
| Table 3: Average High and Low Oral Temperatures and Corresponding Times .....   | 23 |
| Table 4: Physical Strength Test Readings of the Participants during High and<br>Low Oral Temperatures.....              | 25 |
| Table 5: Mental Performance Test Readings of the Participants during High and<br>Low Oral Temperatures.....             | 25 |
| Table 6: Physical Performance between 12:30-2:00pm in Relation to the Lunar Cycle (kg) .....                            | 26 |
| Table 7: Mental Performance between 12:30-2:00pm in Relation to the Lunar Cycle (%).....                                | 26 |
| Table 8: Percentage Change in the Average Physical and Mental Performance during<br>High and Low Oral Temperatures..... | 27 |
| Table 9: Effect of Lunar Cycle on Physical Performance Analysis Using t-test.....                                       | 29 |
| Table 10: Effect of Lunar Cycle on Mental Performance Analysis Using t-test.....  | 29 |

## LIST OF FIGURES

|   |    |
|---|----|
| Figure 1. Circadian rhythm of the Pineal and Adrenal glands (Hastings, 1998).....               | 2  |
| Figure 2. Typical fluctuations of core body temperature over a 24-hour period (Cass, 2006)..... | 3  |
| Figure 3. Correlation between activity level and skin temperature (Wouter et al., 2003).....    | 12 |
| Figure 4. Normal Circadian Sleep Rhythm (Arthur, 2003) .....                                    | 14 |
| Figure 5. Abnormal Circadian Sleep Rhythm (Arthur, 2003) .....                                  | 14 |
| Figure 6. Advanced Force Gauge .....  | 19 |
| Figure 7. Static Pull Strength.....   | 19 |
| Figure 8. Average Physical and Mental Performance at High and Low Oral Temperatures .....       | 28 |
| Figure 9. Average Oral Temperature for All Participants Over a 10-day Period.....               | 28 |
| Figure 10. Rectal Temperature as a Function of Time (Monk <i>et al</i> , 1996).....             | 32 |

## **ABSTRACT**

This thesis studied the temperature circadian rhythm and its relationship with the physical and mental performance of the individuals. The objectives of this study were to determine (1) the effect of temperature circadian rhythm on the mental and physical performance, (2) whether a common oral temperature circadian rhythm pattern exists for all the participants, (3) the times of the day when the participants perform their best and worst in comparison to their highest and lowest temperatures respectively, (4) find out whether the effect of the oral temperature circadian rhythm on the physical and mental performance is different in males and females, and (5) the effect of lunar cycle on the physical and mental performance.

In order to achieve the above-mentioned objectives, ten participants (5 males and 5 females between the ages of 20-28 years) were tested. Each participant was required to record his/her body temperature every hour over a 13-hour period for about a week. Based on this data, the participants' highest and lowest temperatures were determined. Each participant was given a physical and a mental performance test at the times corresponding to his/her highest and lowest temperatures. Finally, the lunar calendar was used to test the effect of the lunar cycle on the physical and mental performance of the participants.

The results of the experiment show that during the time corresponding to high oral temperatures, the participants' physical performance increased by 9.3 percent, and the mental performance increased by 4.6 percent compared to their low temperatures. The participants, upon analysis of the data, also exhibited a common pattern in their temperature circadian rhythms. The results showed that on average, the participants' body temperature started increasing around 9:30am and kept increasing until 8:30pm. In addition to that, it was also found out that there was an insignificant difference in the average physical performance increase in males (9.38lbs) and

females (9.39lbs); however, mental performance increased by a greater percentage, in females (5.2) as compared to males (4.07). Finally, the lunar cycle had no effect on the physical and mental performance of the participants.

# CHAPTER1: INTRODUCTION

Performance is directly related to productivity therefore improved physical and mental performance will lead to higher productivity and lower the risks of work related injuries. According to Proverbs *et al.* (1999b), productivity translates directly into cost savings and profitability, which is the main goal of every business. This study will prove beneficial for the work industry since it targets improvement of the physical and mental performance of individuals in relation to the temperature circadian rhythm. Since the whole study is based on the body temperature, it is important to understand the circadian rhythm because temperature is one of the many circadian rhythms that play a vital role in the living organisms' proper functionality. By gaining a proper understanding of the concepts involved behind these cycles, we can actually take advantage of the body's natural rhythm to positively impact productivity in a working environment.

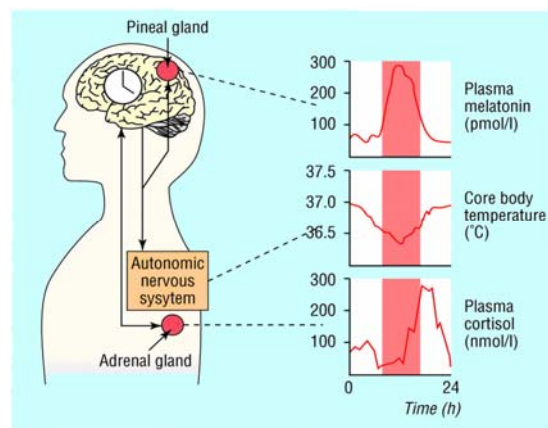
In the 17<sup>th</sup> century, De Mairan, Jean-Jacques discovered the circadian rhythm. He placed a heliotrope (an herb that turns in the direction of sun) in his closet, away from sunlight, in order to investigate the heliotrope's inclination to respond to the sun, (Willis, 1990). De Mairan noticed that twenty-four hour patterns (Circadian Rhythms) continued to exist in the movement of the heliotrope's leaves even when the heliotrope was isolated from external stimulus, which in this case was the sun (Wikipedia Foundation Inc, 2006).

The word Circadian Rhythm comes from the Latin *circa*, "around", and *dies*, "day" which means around a day (Quraishi, 2002). Circadian Rhythm can be defined as the daily biological rhythm. This biological rhythm or the internal clock is sometimes referred to as the biological clock, which exists in mammals, plants, fungi, insects and so on, and it runs on a 24-hour cycle.

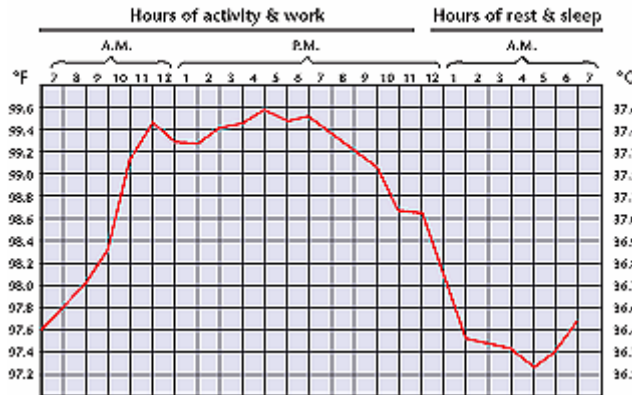
In general, circadian rhythm can be defined by the following criteria (Wikipedia Foundation Inc, 2006):

1. The rhythm persists in constant conditions (For example constant dark) with a period of 24 hours.
2. The rhythm period can be reset by exposure to light or dark pulse.
3. The rhythm proceeds at the same rate within a range of temperatures

The human body has over a hundred circadian rhythms and each unique 24-hour cycle influences an aspect of the bodily function including the sleep-wake cycle, temperature, hormone levels, heart rate, blood pressure, and even the pain threshold (Mayo Foundation for Medical Education and Research, 1995). Figure 1 shows the circadian rhythm of the Pineal and Adrenal glands and the Autonomic nervous system over a 24-hour period. As mentioned earlier, there are over a hundred organs/systems each having their own unique rhythm that they operate on. Figure 2 shows the typical fluctuations of core body temperature over a 24-hour period.



**Figure 1.** Circadian rhythm of the Pineal and Adrenal glands (Hastings, 1998)



**Figure 2.** Typical fluctuations of core body temperature over a 24-hour period (Cass, 2006)

### 1.1 Problem Definition

The available literature survey indicates that not much has been done when it comes to the evaluation of the effect of circadian rhythm on the mental performance in humans and no research were found on the effect of the circadian rhythm on the physical performance. Various studies have looked at the circadian rhythm of hormones such as melatonin and plasma cortisol, core body temperature, skin temperature, and the circadian sleep-wake rhythms and their effect on the human body; however, no research has been conducted on the effect of the oral temperature circadian rhythm on the physical and mental performance of individuals. In addition, the literature lacks research on the effects of lunar cycle on human performance.

### 1.2 Objectives

The proposed study focused on the performance of participants by determining (1) Effect of oral temperature circadian rhythm on the mental and physical performance, (2) If a common oral temperature circadian rhythm pattern exists for all the participants or each participant has a unique rhythm, (3) Times of the day when the participants perform their best and worst in comparison to their highest and lowest temperatures respectively, (4) If the effect of the

temperature circadian rhythm on the physical and mental performance is different in males and females, and (5) Effect of lunar cycle on the physical and mental performance.

## **CHAPTER 2: LITERATURE REVIEW**

Circadian rhythms are of primary interest when it comes to the functionality of living organisms. It is extremely important to understand the factors that have an impact on the 24 hour cycle, circadian rhythm, in human beings either positively or negatively for healthy and productive functionality of human beings. Most researchers tried to find the impact of various circadian rhythms on the overall functionality of human beings in order to elevate the level of performance in human beings directly or indirectly. The following section is a review of literature related to various studies performed on different circadian rhythms to determine the impact on the performance.

### **2.1 Affect of Circadian Rhythm on Various Bodily Functions and Performance**

The human body has over a hundred circadian rhythms but some circadian rhythms have been studied more than others. In case of animals, the most extensive studies are conducted in mice and drosophila (housefly) because their clock genes function very similar to human beings. There are a variety of circadian rhythms that influence physiological functioning in humans. Among them are rhythms in the sleep-wake cycle, glucose uptake, core body temperature, neurotransmitter function, heart rate, and circulating hormones (Folkard, 1993; Hasher, 2005; Hrushesky, 1994; Monk, 1989; Moore-Ede *et al.*, 1982). Proper functionality of human beings translates to physical and mental well being which in turn becomes a determining factor of productivity.

#### **2.1.1 Circadian Phase Shift and Neurobehavioral/Cognitive Functioning**

Productivity has been the most critical component of any industry and much research has been conducted to determine factors that could increase productivity in the industrial environment. Eastman *et al.* (1994) conducted a study related to productivity to determine

circadian rhythm adaptation to nightshift work. They compared the contributions of bright light during the night shift and dark goggles during daylight for phase shifting of the circadian rhythm of temperature to realign with a 12-hour shift of sleep. Both bright light and goggles were significant factors for producing circadian rhythm phase shifts. The combination of bright light plus goggles was the most effective, whereas the combination of dim light and no goggles was the least effective.

The temperature rhythm either phase advanced or phase delayed when it aligned with daytime sleep; however, when participants did not have goggles, only phase advances occurred. Goggles were necessary for producing phase delays. The most likely explanation is that daylight during the travel-home window after a night shift inhibits phase-delay shifts, and goggles can prevent this inhibition. Larger temperature-rhythm phase shifts were associated with better subjective daytime sleep, less subjective fatigue, and better mood.

Productivity goes hand in hand with performance and to yield productive results, performance must be elevated by providing suitable working conditions along with the individual's own capabilities and limitations. A study conducted at the Harvard Medical School in Boston by Dijk *et al.* (1992) aimed at determining the circadian and sleep/wake dependent aspects of subjective alertness and cognitive performance. Circadian and sleep/wake dependent processes underlying variations in subjective alertness and cognitive performance were assessed in a constant routine protocol and in a protocol in which the sleep/wake cycle was uncoupled from the output of the endogenous circadian pacemaker. In the latter protocol, the contribution of a sleep/wake dependent process and a circadian process to alertness and performance were separated by folding the data at either the period of the sleep/wake cycle or at the period of the endogenous circadian body temperature rhythm. This analysis revealed that prior wakefulness

within a range of 0-18 hours (individual stays awake 18 hours prior to his actual wake time) significantly reduced alertness and performance and that the circadian rhythm of core body temperature paralleled the circadian rhythm of alertness and performance.

Hans *et al.* (2000) conducted a study to determine the role of the circadian rhythm in fatigue, alertness, and cognitive performance. The study concluded by saying that the circadian drive for wakefulness, the homeostatic drive for sleep, and various endogenous and exogenous masking factors simultaneously affect neurobehavioral functioning. When alertness and performance are considered, masking factors such as demand characteristics of the experiment, distractions by irrelevant stimuli, boredom and motivational factors, stress, food intake, posture, ambient temperature, background noise, lighting conditions, and drug intake (e.g., caffeine) cannot be regarded as mere undesirable influences that should be ignored or controlled. Rather, they are an integral part of the regulation of neurobehavioral functions.

Manipulation of these endogenous and exogenous stimuli may affect the circadian and homeostatic systems via interactions, which cannot yet be accurately quantified. Thorough understanding of circadian rhythmicity in neurobehavioral functions is important when either the sleep–wake rhythm is displaced, as is the case on night-work or when the circadian rhythm is displaced, as is the case after transmeridian flights. In such situations the circadian and homeostatic systems interact to decrease alertness and performance. In fact, performance deficits and fatigue may reach dangerous levels, inducing opportunities for accidents (Leproult *et al.* 2002).

Another study conducted by Johnson *et al.* (1992) reported that the circadian rhythm of short-term memory varies in parallel with the circadian rhythms of subjective alertness, calculation performance, and core body temperature. They suggested that the human circadian

pacemaker, which drives the body temperature cycle, is the primary determinant of endogenous circadian variations in subjective alertness and calculation performance as well as in the immediate recall of meaningful material.

When it comes to performance, age is a vital factor that determines an individual's capacity to accomplish mental and physical tasks. In general, most children can perform better in the morning, younger adults prefer afternoon or evening times, and older adults prefer morning times for both intellectual and physical activities. In addition, inscribed within this range are substantial individual differences. As a result of these age and individual differences, general conclusions about the "optimal" time of day - conclusions that characterize most people regardless of age - can rarely be made (Hasher *et al.*, 2005). However, age does make a difference in the circadian arousal for cognitive functioning. A study conducted by May *et al.* (1993) indicated that there was a major shift in arousal patterns from childhood to young adulthood and from young adulthood to old age. Furthermore, there were comparable age-related phase shifts that were seen for older nonhuman animals as well. These age-related shifts have been linked to changes in a wide range of circadian rhythms that affect sleep-wake cycles, eating and drinking patterns, glucose uptake, and heart rate, as well as circulating hormones (e.g., melatonin, adrenocorticotropic hormone), and neurotransmitter function e.g. acetylcholine, nor-epinephrine (Gallagher *et al.*, 1994; Hrushesky, 1994; Stone, 1989).

Another study based on younger and older adults who were tested early in the day (8AM or 9 AM) or late in the afternoon (4PM or 5 PM) – clearly showed that younger adults' scores improve from the morning testing times to the afternoon times, while those of older adults declined. The 35% advantage for younger adults over older adults tested in the afternoon was

reduced to a 20% advantage when both age groups were tested at near their peak times, morning for older adults and afternoon for most young adults (Hasher and Wincour, 2002).

### **2.1.2 Circadian Rhythm and Temperature**

The most well-known circadian rhythm is that of body temperature. This rhythm persists even when the individual is confined to bed for the entire 24 hours, when the physical activity is varied, or if the person fasts. Pulse rate and blood pressure also peak around the same time as body temperature (Willis, 1990). The human body temperature is lowest when an individual is inactive. However, activity can make the temperature rise. But despite these factors, the temperature also follows a definite circadian rhythm (Mayo Foundation for Medical Education and Research, 1995).

A study conducted by Cagancci *et al.* (1999) showed that Melatonin had a significant impact on the circadian rhythm of core temperature in humans. The results of their study led to the fact that circadian rhythms of melatonin and BTc (core body temperature) are inversely coupled. Melatonin is secreted by the pineal gland in the brain and is important in the regulation of many hormones in the body. Among its key roles, melatonin controls the body's circadian rhythm, an internal 24-hour time-keeping system that plays an important role in when we fall asleep and when we wake up. Darkness stimulates the release of melatonin and light suppresses its activity. Normal melatonin cycles are disrupted when we are exposed to excessive light in the evening or too little light during the daytime. For example, jet lag, shift work, and poor vision can disrupt melatonin cycles (University of Maryland Medical Center, 2004). Another study was conducted to see circadian rhythms in human performance. The study suggested that temperature changes may reflect changes in the metabolic processes which could facilitate the performance by speeding up the rate at which information is processed (Monk *et al.*, 1997).

Kenneth et al. (2002) studied the relationship between alertness performance and body temperature in humans. The findings of their research demonstrated a positive relationship between body temperature and performance while controlling for circadian phase and hours awake. The results indicated that within the normal circadian range of body temperature, higher body temperature represented physiological arousal that enhanced neurobehavioral and cognitive functioning involving performance measures such as working memory, subjective alertness, and visual attention. Another study conducted by Holland et al. (1985) determined the effects of raised body temperature on reasoning, memory, and mood. Participants were tested for memory registration and recall. The results of this study showed that increase in core temperature was associated with a significant increase in the speed of performance of the tests, by 11 and 10%, respectively.

Colshaw et al. (1983) studied the effect of lowering body temperature on memory registration and speed of reasoning. Aspects of cognitive function were subsequently tested at low core temperature and it was found out that memory registration was impaired progressively when core temperature fell from about 36.7 degrees C. Also, at core temperatures of 34-35 degrees C the impairment caused loss of approximately 70% of data that could normally be retained. Finally, on a two-digit calculation test, speed of performance was impaired by about 50% at a core temperature of 34-35 degrees Celsius.

However, depending on what type of temperature is being measured, whether it is oral, core, skin, the results may vary despite the fact that the oral, skin, and ear temperatures (TMD-Tympanic Membrane Derived) are reflections of the rectal temperature. This is because, under ideal conditions, the temperatures should be same as the rectal temperature, however, temperature variations caused by eating or drinking hot or cold foods and drinks, exercising,

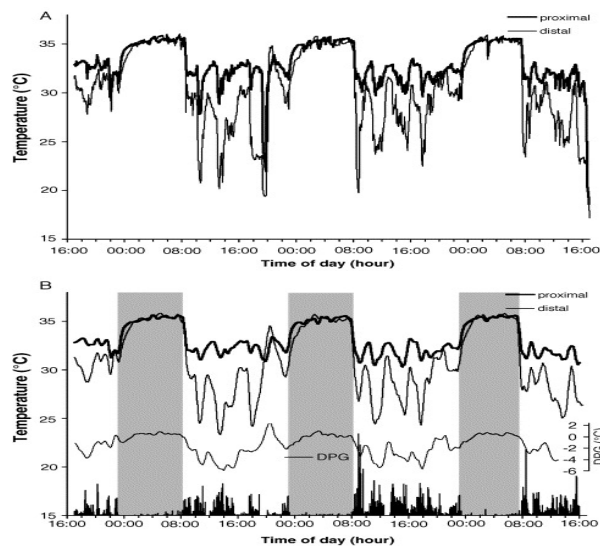
smoking, and nature of clothing could affect the oral and skin temperatures. Rabinowitz *et al.* (1996) conducted a study to measure the effects of anatomic site, oral stimulation, and body position on estimates of body temperature. The results indicated that the mean rectal temperatures exceeded concurrent oral readings by 0.8 degrees F +/- 0.7 degrees F, which, in turn, exceeded concurrent tympanic membrane readings by 0.7 degrees F +/- 2.0 degrees F. Also, Mastication and smoking both caused significant increases in oral temperature that persisted for greater than 20 minutes. Drinking ice water caused a significant but more transient decrease in oral temperature. Body position exerted a modest effect on rectal temperature readings, but did not significantly affect oral or tympanic membrane readings.

Another study conducted by Terndrup *et al.* (1989) investigated the change in body temperature measurements over time following ingestion of ice water, hot water, and smoking. It was concluded that hot and cold liquids significantly influence oral temperature measurement for seven to nine minutes following ingestion, ear temperature was unaffected by liquid ingestion and may allow accurate measurement of body temperature. The mean initial temperatures were rectal, 37.1 +/- 0.5 degrees C (mean +/- S.D.); oral, 36.4 +/- 0.4 degrees C; and TMD, 37.4 +/- 0.4 degrees C. Maximal mean oral temperature change was greatest at 1.5 minutes after hot, +0.9 +/- 0.1 degrees C, and cold, -1.2 +/- 0.2 degrees C, water.

Karauchi *et al.* (1994) studied the circadian rhythm of heat production, heart rate, and skin core temperature under unmasking conditions in men. The circadian rhythm over 30.5h in rectal and skin temperatures was determined and it was observed that the infra-clavicular and stomach temperature were the closest to the rectal temperature. In other words, they showed the least variation in comparison to the rectal temperature. Where as the foot and hand temperatures varied highly in comparison to the rectal temperature

Wouter *et al.* (2006) conducted a study to evaluate wireless determination of skin temperature using iButtons. The use of iButtons has been prevalent in studies on circadian rhythms, sleep, and cardiac surgery and has been extremely beneficial for measuring skin temperatures under circumstances where wired instruments are unpractical and fast responses are not required. The results of this study suggested that unlike the well-known positive correlation between cognitive activity and core body temperature, there was a negative correlation between autonomic activity level and skin temperature in everyday life. Figure 3 shows the correlation pattern. The negative correlation between activity level and skin temperatures is clear from the graphs.

Figure 3 shows the time spent in bed (grey area) and the activity level (black columns, arbitrary units from simultaneous actigraphic recording). Moreover, the distal to proximal skin temperature gradient (DPG) is shown on a separate axis. It can be seen that the marked and simultaneous nocturnal elevation of both proximal and distal temperature barely occurs during wakefulness, indicating different thermoregulatory state during the sleep period.



**Figure 3.** Correlation between activity level and skin temperature (Wouter et al., 2003)

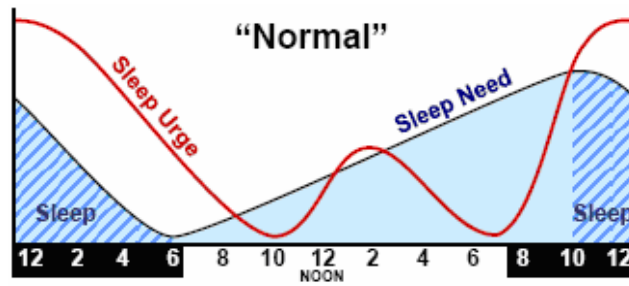
However, more research has been conducted in the core body temperature and the circadian rhythm of core body temperature (BTc), with maxima during the day and minima at night, is normally coupled with the sleep-wake cycle.

### **2.1.3 Circadian Rhythm and Sleep-Wake Cycle**

The sleep-wake cycle is a very commonly researched area when it comes to circadian rhythms. The sleep-wake cycle of an organism can be disrupted very easily upon exposition to factors like lighting, time difference, which results in jetlag, and so on. A persistent or recurrent pattern of sleep disruption leading to excessive sleepiness or insomnia is due to a mismatch between the sleep-wake schedule required by the person's environment and his or her circadian sleep-wake pattern. The sleep disturbance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning, it does not occur exclusively during the course of another sleep disorder or other mental disorders. This disturbance is not due to the direct physiological effects of a substance (e.g., a drug of abuse, a medication) or a general medical condition (American Psychiatric Association, 1994).

A small but growing literature has examined children's morningness-eveningness preferences. Studies reported that MEQ (morningness-eveningness questionnaire) scores decreased significantly with age, moving towards an evening preference, and that reported sleep disturbances (e.g. restless sleep) were related to eveningness (Bearpark and Michie, 1987). Carskadon et al. (1993) reported a phase delay in children's sleep and wake-up time and concluded that biological rather than psychosocial (e.g., birth order and peer group) factors are causes of this sleep phase delay. Figure 4 and

Figure 5 show normal pattern and the disrupted pattern, respectively.



Normal circadian sleep rhythm. Sleep urge is greatest at night with a small increase at mid day. Sleep need increases throughout the waking hours and is replenished during sleep.

**Figure 4.** Normal Circadian Sleep Rhythm (Arthur, 2003)



Missing sleep by awakening earlier than normal will result in an increased sleep burden above normal levels, requiring increased sleep to eventually repay the additional sleep debt.

**Figure 5.** Abnormal Circadian Sleep Rhythm (Arthur, 2003)

Another study showed that there was a relationship between the sleep-wake cycle and psychiatric disorders. For over 30 years, sleep deprivation has been described as a treatment for depression sleep deprivation. However, in certain psychiatric disorders, disruption in the sleep-wake cycle caused depression. It was also found that there were significant disturbances in sleep continuity in patients with chronic Schizophrenia; but these disturbances were different from those observed in depression (Biovin, 2000).

#### **2.1.4 Disturbances in Circadian Rhythm Pattern**

Disturbance in the circadian rhythm pattern can affect an organism to a great extent. Circadian rhythm disturbances can be categorized into two main groups: transient disorders (e.g., jet lag; changed sleep schedule due to work, social responsibilities, and illness) and chronic disorders. The most common chronic disorders are delayed sleep-phase syndrome (DSPS), advanced sleep-phase syndrome (ASPS), and irregular sleep-wake cycle. Katzenberg *et al.* (2000) suggested genetic correlation (i.e. clock polymorphisms) with circadian rhythm patterns. Salti *et al.* (1995) conducted a study on circadian locomotor activity and core-body temperature rhythms in Alzheimer's disease (AD). These findings suggested that a subgroup of AD patients with impaired endogenous pacemaker function may have a diminished capacity to synchronize the rhythm of core-body temperature with the circadian cycle of rest-activity. Another study conducted by Claudia Trenkwalder *et al.* (1999) explored the circadian rhythm of periodic limb movements (PLM) and sensory symptoms of restless legs syndrome (RLS). The results of this study showed that the highest PLM counts occurred on the falling phase of the circadian temperature curve whereas the lowest PLM counts occurred on the rising phase of the curve. It was therefore concluded that the PLM and sensory symptoms in RLS are influenced by a circadian rhythm.

A study conducted by Czesiler *et al.* (1980) showed a correlation between the timing of REM (Rapid Eye Movement) sleep and the circadian rhythm of the body temperature. The percentage of sleep time spent in REM sleep varied significantly with the phase of that near-24-hr body temperature cycle. The peak in REM sleep propensity (RSP) occurred on the rising slope of the average body temperature curve, coincident with the phase of peak sleep tendency. This was associated with a significantly increased REM episode duration and shortened REM latency

(including sleep-onset REM episodes), but without a significant change in the REM-NREM cycle length. It was therefore concluded that there is an endogenous circadian rhythm of REM sleep propensity which is closely coupled to the body temperature rhythm and is capable of free-running with a period different from both 24 hr and the average period of the sleep-wake cycle.

## **2.2 Findings of Literature Review**

It is clear from the above literature that circadian rhythms are studied extensively and most of the literature available focuses on some primary circadian rhythms such as the core temperature, sleep-wake rhythms, hormonal rhythms and the skin temperature in relation to cognitive and autonomic functioning in individuals. However, there is no literature available on the oral temperature circadian rhythm and its impact on the physical and mental performance in individuals or the degree of impact of circadian rhythms on males and females. Apart from that, there is no research or literature available on the impact of lunar cycle on human performance.

This study aims at improving the performance of participants by determining the effect of the oral temperature circadian rhythm on the physical and mental performance. In addition, the study will try to determine whether individuals have a common circadian rhythm pattern or each individual has a unique pattern. Another goal of this study will be to identify how the oral temperature circadian rhythm affects our day-to-day performance physically and mentally, and whether the impact of oral temperature circadian rhythm on the mental and physical performance in males and females differs or is the same. In addition to that, the study will also determine whether the lunar cycle influences the physical and mental performance in individuals.

## **CHAPTER 3: METHODOLOGY**

### **3.1 Procedure**

This study aimed at investigating the influence of oral temperature circadian rhythm by achieving five primary objectives which are as follows:

1. Determine the effect of temperature circadian rhythm on the mental and physical performance.
2. Determine whether a common temperature circadian rhythm pattern exists for all the participants or each participant has a unique rhythm.
3. Determine the times of the day when the participants perform their best and worst in comparison to their highest and lowest temperatures, respectively.
4. Determine whether the effect of the temperature circadian rhythm on the physical and mental performance is different in males and females or the same.
5. Determine the effect of lunar cycle on the physical and mental performance.

#### **3.1.1 Participants**

In order to achieve the above mentioned objectives, 10 healthy participants (5 male and 5 female College students between the ages of 20-28 years) were chosen. The participants were given a consent form to read and sign. Some basic information such as the age, gender, and height were recorded for each participant at the beginning of the experiment and the experimental procedure was explained to each participant in detail.

#### **3.1.2 Equipment**

This study utilized a Dillon Load Cell to measure the static arm strength, a display unit (Figure 6) known as the Advanced Force Gauge (AFG) that displayed the arm strength readings in lbs, a custom made 18 inch handle that was connected to the load cell for applying force, and a

digital thermometer (Relion 9-second flex or 9 second read-out) to measure oral temperature.

Further more, the equipment comprised of a platform with a vertical support to which the handle was connected using the load cell, which in turn was connected to the Advanced Force gauge via a cable.

### **3.1.3 Data Acquisition**

Each participant was asked to record his/her body temperature over a period of 10 days from the 7:30 am until 8:30 pm. The days were chosen carefully to ensure that the first three days of lunar cycle were encompassed in the 10-day period. Based on that, the times corresponding to the average highest and lowest oral temperatures for each participant for 10 days were determined. Each participant's physical and mental performance was then measured at the times corresponding to their average high and low temperatures. Apart from that, each participant's strength was measured between 12:30pm to 2:00pm over the 10-day period to determine the impact of lunar cycle on the performance. The following sections describe the procedure for carrying out the performance tests.

### **3.1.4 Physical Strength**

The participants' physical strength was measured by giving them the static arm pull test using a static strength model (Aghazadeh and Ayoub, 1985). Figure7 shows the testing method which involved adjustment of the handle of the equipment such that the forearms of the participant were flexed at 90 degrees and the upper arms were vertical, parallel, and adjacent to the torso. The participant was required to stand erect with legs and back straight and with feet flat. The participant was the required to hold sides of the handle bar connected to the load cell and exert the force upward and vertically in the sagittal plane (Aghazadeh *et al.*, 1997). The exerted force was generated by the arms only and shoulder movement was avoided. Each

participant was asked to pull the handle gradually with maximum strength without jerking and the strength readings were displayed on the gauge in lbs. The procedure was repeated three times per participant, to ensure accuracy and the average was computed.



**Figure 6.** Advanced Force Gauge



**Figure 7.** Static Pull Strength

### 3.1.5 Mental Strength

In addition to the physical strength, the mental performance was also determined by giving each participant a set of unbiased questions that comprised of simple addition and subtraction, and cognitive type problems. The grading scale was based on 100 points with 50 points assigned the Suduko puzzle (Table 1) and 50 remaining to the first three questions (16.67 points each). It should also be noted that different questions were used for the high temperature testing and low temperature testing so the participants would not be able to recall answers, which would affect the accuracy of the data. An example of the mental performance test is given below. The complete test is given in Appendix B.

#### Sample of Mental Performance Test

1.  $157 + 326 =$
2.  $284 - 432 =$
3. How many animals of each type did Moses take on the ark?
4. Fill each row and column in the Suduko Puzzle without repeating the number of rows and column.

Table 1: Suduko Puzzle

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
|   |   |   |   | 1 | 8 |   | 9 |
| 7 |   |   | 9 |   | 6 |   |   |
| 1 | 8 |   |   | 6 |   |   | 2 |
|   | 4 | 8 |   |   |   |   | 7 |
| 5 |   |   | 9 | 3 |   |   | 6 |
| 6 |   |   |   |   | 4 | 3 |   |
| 2 | 6 |   | 8 |   |   |   | 4 |
|   |   | 4 |   | 6 |   |   | 8 |
| 8 |   | 1 | 2 |   | 5 |   |   |

It should be noted that the participants were unaware of their high and low temperatures when they came in for testing. This was done to ensure that the data was unbiased because if the

participants knew their temperatures prior to testing, their performance could be influenced due to the placebo effect.

### **3.2. Lunar Cycle and Performance**

Another criterion that was measured while conducting the experiment was the effect of lunar cycle on the physical and mental performance of the participants. This was accomplished by testing each participant's mental and physical performance between 12:30 pm to 2:00 pm for 10 days using the procedures mentioned in sections 3.2.1 and 3.2.2. Due to availability issues, only six participants were used for testing the impact of lunar cycle on mental performance. Out of the 10 days, three days, 11-13-Jun, comprised of the full moon period. This interval was chosen because that is when the moon is full or new, the gravitational pull of the moon and sun are combined and the gravitational attraction of both the sun and the moon on the earth is maximum (Cooley, 2002). The time interval of 12:30-2:00 pm was used because that is when the gravitational pull of the moon is the strongest at any given day. Hence, it would be possible to determine the lunar effects, if any, on the physical and mental performance of the participants.

It should be noted that the full moon phase started on the 11<sup>th</sup> of June and continued until the 13<sup>th</sup> of June. The 12<sup>th</sup> and 13<sup>th</sup> of June were chosen because the impact of full moon, if any, can be monitored in the first 3 three days of the full moon phase. In order to determine any possible effect of the lunar cycle on the performance, the data from 8<sup>th</sup>, 9<sup>th</sup>, 10<sup>th</sup>, 14<sup>th</sup>, 15<sup>th</sup>, 16<sup>th</sup>, and 17<sup>th</sup> of June were compared to the 11<sup>th</sup>, 12<sup>th</sup>, and 13<sup>th</sup> of June individually for both physical and mental performance using t-test.

## CHAPTER 4: RESULTS

### 4.1 Data Interpretation

Once the tests were complete, the data for temperature, physical performance, and mental performance were tabulated. The following sections provide an overview of the data that was utilized to derive the results

#### 4.1.1 Temperature

The temperatures of all the participants were recorded daily for 13 hours (7:30am-8:30pm) over the 10-day period and the average hourly temperatures for each participant were calculated from the data. The detailed data for each participant is given in Appendix C. Once that was achieved, the hourly average temperatures of all the participants were computed as shown in Table 2. In addition, the times during each participant's average high temperature and low temperatures were identified as shown in (Table 3).

Table 2: Average Oral Temperature of All the Participants over a 10-Day Period

| Time    | Temperature (F) |
|---------|-----------------|
| 7:30 am | 97.03           |
| 8:30 am | 97.06           |
| 9:30 am | 97.00           |
| 10:30am | 97.18           |
| 11:30am | 97.21           |
| 12:30pm | 97.26           |
| 13:30pm | 97.47           |
| 14:30pm | 97.51           |
| 15:30pm | 97.55           |
| 16:30pm | 97.54           |
| 17:30pm | 97.66           |
| 18:30pm | 97.67           |
| 19:30pm | 97.76           |
| 20:30pm | 97.76           |

Table 3: Average High and Low Oral Temperatures and Corresponding Times

| Participants | Time of Day | Average High Temperature | Time of Day | Average Low Temperature |
|--------------|-------------|--------------------------|-------------|-------------------------|
| Males        | 16:30       | 97.41                    | 10:30       | 96.61                   |
| Males        | 16:30       | 98.10                    | 8:30        | 97.17                   |
| Males        | 20:30       | 97.97                    | 8:30        | 97.13                   |
| Males        | 20:30       | 97.14                    | 7:30        | 95.37                   |
| Males        | 20:30       | 98.25                    | 7:30        | 97.37                   |
| Females      | 20:30       | 97.90                    | 7:30        | 97.24                   |
| Females      | 19:30       | 97.98                    | 16:30       | 97.51                   |
| Females      | 14:30       | 97.98                    | 7:30        | 97.51                   |
| Females      | 20:30       | 98.12                    | 7:30        | 96.66                   |
| Females      | 19:30       | 97.90                    | 11:30       | 95.54                   |

#### 4.1.2 Physical Strength

Based on table 3, the participants were tested for their physical strength at the times corresponding to their high temperatures and low temperatures using the procedure described in section 3.2.1. The data were recorded in Kg as shown in Table 4.

#### 4.1.3 Mental Performance

Another variable that was measured was the mental performance of each participant. This was achieved by using the procedure described in section 3.2.2 and just like the physical strength, the participant's mental performance was determined during the times corresponding to their high temperatures and low temperatures. The results were based on a 100 point scale expressed in percentage as shown in Table 5

#### 4.1.4 Lunar Cycle and Performance

The participants were tested between 12:30 to 2:00 pm, since the impact of the lunar cycle, is observed at that time as stated earlier, for 10 days starting from June 8 to June 17. Out of these

10 days, three days, 11-13-Jun, comprised of the full moon period. The data was recorded in two separate tables (Tables 6 and 7) for physical strength and mental performance respectively.

## **4.2 Statistical Analysis**

Once the data were obtained, statistical analysis was conducted to test the following hypotheses.

$H_{01}$  = Temperature circadian rhythm does not affect individuals' performance

$H_{11}$  = Temperature circadian rhythm affects individuals' performance

$H_{02}$  = A common circadian rhythm pattern does not exist for individuals

$H_{12}$  = A common circadian rhythm pattern exists for individuals

$H_{03}$  = Effect of temperature on male and female performance is the same

$H_{13}$  = Effect of temperature on male and female performance is not the same

$H_{04}$  = Lunar cycle has an impact on individuals' performance

$H_{14}$  = Lunar cycle does not have an impact on individuals' performance

(Note- performance level includes both physical and mental performance)

### **4.2.1 Hypothesis 1**

$H_{01}$  = Temperature circadian rhythm does not affect individuals' performance

$H_{11}$  = Temperature circadian rhythm affects individuals' performance

The data from Tables 4 and 5 were analyzed using t-test at a significance level of  $\alpha=0.05$ . The test yielded a value of 0.00005, which showed that at  $\alpha=0.05$  there was a significant effect of temperature on the physical and mental performance.

Table 4: Physical Strength Test Readings of the Participants during High and Low Oral Temperatures

| Subject | Age | Height (cm) | Weight (Kg) | Physical Strength at High Temperature (kg) | Physical Strength at Low Temperature (kg) |
|---------|-----|-------------|-------------|--|---|
| 1 (M)   | 28  | 170         | 67.27       | 30.83                                      | 28.34                                     |
| 2 (M)   | 25  | 175         | 77.27       | 26.97                                      | 24.14                                     |
| 3 (M)   | 21  | 194         | 74.09       | 30.90                                      | 27.83                                     |
| 4 (M)   | 24  | 168         | 75.45       | 30.31                                      | 28.19                                     |
| 5 (M)   | 25  | 177         | 71.36       | 32.42                                      | 30.05                                     |
| 6 (F)   | 27  | 163         | 65.91       | 19.80                                      | 18.48                                     |
| 7 (F)   | 23  | 155         | 54.09       | 13.78                                      | 12.94                                     |
| 8 (F)   | 26  | 140         | 58.18       | 11.36                                      | 10.29                                     |
| 9(F)    | 24  | 159         | 70.45       | 12.64                                      | 11.44                                     |
| 10(F)   | 25  | 154         | 66.81       | 10.52                                      | 9.39                                      |

Table 5: Mental Performance Test Readings of the Participants during High and Low Oral Temperatures

| Subject | Age | Height (cm) | Weight (Kg) | Mental Performance at High Temperature (%) | Mental Performance at Low Temperature (%) |
|---------|-----|-------------|-------------|--|---|
| 1 (M)   | 28  | 170         | 67.27       | 71.98                                      | 68.21                                     |
| 2 (M)   | 25  | 175         | 77.27       | 57.45                                      | 53.45                                     |
| 3 (M)   | 21  | 194         | 74.09       | 70.15                                      | 68.33                                     |
| 4 (M)   | 24  | 168         | 75.45       | 68.74                                      | 67.21                                     |
| 5 (M)   | 25  | 177         | 71.36       | 50.38                                      | 49.21                                     |
| 6 (F)   | 27  | 163         | 65.91       | 77.83                                      | 75.5                                      |
| 7 (F)   | 23  | 155         | 54.09       | 50.26                                      | 46.98                                     |
| 8 (F)   | 26  | 140         | 58.18       | 72.89                                      | 70.42                                     |
| 9 (F)   | 24  | 159         | 70.45       | 48.67                                      | 45.91                                     |
| 10 (F)  | 25  | 154         | 66.81       | 55.34                                      | 52.11                                     |

Table 6: Physical Performance between 12:30-2:00pm in Relation to the Lunar Cycle (kg)

| Participant | 8Jun  | 9Jun  | 10Jun | 11Jun | 12Jun | 13Jun | 14Jun | 15Jun | 16Jun | 17Jun |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1M          | 28.75 | 29.14 | 28.74 | 29.34 | 28.56 | 29.59 | 29.55 | 28.73 | 28.75 | 29.34 |
| 2M          | 26.15 | 26.2  | 26.05 | 26.01 | 26.30 | 26.01 | 26.18 | 26.60 | 26.17 | 26.03 |
| 3M          | 29.20 | 29.18 | 29.03 | 29.43 | 29.62 | 28.84 | 28.03 | 29.45 | 29.35 | 29.69 |
| 4F          | 9.95  | 10.02 | 9.84  | 9.76  | 9.93  | 10.04 | 9.927 | 10.26 | 9.98  | 10.00 |
| 5F          | 19.39 | 19.35 | 19.47 | 19.56 | 19.54 | 19.48 | 20.50 | 19.38 | 19.64 | 19.49 |
| 6F          | 13.16 | 13.15 | 13.20 | 13.11 | 13.16 | 13.35 | 13.10 | 13.43 | 13.73 | 13.58 |
| Average     | 28.75 | 29.14 | 28.74 | 29.35 | 28.56 | 29.59 | 29.55 | 28.73 | 28.75 | 29.35 |

Table 7: Mental Performance between 12:30-2:00pm in Relation to the Lunar Cycle (%)

| Participant | 8Jun  | 9Jun  | 10Jun | 11Jun | 12Jun | 13Jun | 14Jun | 15Jun | 16Jun | 17Jun |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1M          | 70.58 | 69.65 | 70.5  | 68.5  | 69.26 | 69.98 | 68.98 | 69.5  | 69    | 69.78 |
| 2M          | 56.36 | 56.5  | 55.33 | 57.45 | 56.77 | 56.5  | 57.21 | 57.5  | 58    | 55.88 |
| 3M          | 70.33 | 70    | 69.38 | 69.5  | 69.78 | 70.5  | 68.42 | 69.11 | 67.58 | 68    |
| 4F          | 62.88 | 63.51 | 62.5  | 62.88 | 63.46 | 63.5  | 62.67 | 63.22 | 64.77 | 63.75 |
| 5F          | 75    | 75.5  | 78.42 | 77.98 | 75.67 | 76.37 | 76.88 | 76    | 74.36 | 75.68 |
| 6F          | 47.28 | 47.95 | 48.67 | 49.98 | 47.68 | 50.05 | 50.44 | 49.98 | 50    | 48.5  |
| Average     | 63.74 | 63.85 | 64.13 | 64.1  | 64.22 | 63.95 | 63.59 | 64.38 | 63.77 | 64.48 |

This was further confirmed by determining the percentage change in the physical and mental performance from high to low temperatures, which is summarized in Table 8. It can be seen that physical strength increased by about 9.3 percent from low temperature to high temperature and the mental performance increased by 4.6 percent from low temperature to high. The difference can be seen visually in Figure 8. Even though the mental performance was affected by a smaller percentage as compared to the physical performance, it was still significant. In addition to that, the data from Table 4 was analyzed further to see the difference between the physical strength in

males and females. It was found that the female participants' physical strength was about 45% of that of male participants.

#### 4.2.2 Hypothesis 2

$H_{02}$  = A common circadian rhythm pattern does not exist for individuals

$H_{a2}$  = A common circadian rhythm pattern exists for individuals

Hypothesis 2 was tested to determine the existence of a common temperature circadian rhythm pattern for all participants. The average temperatures of all the participants over a 10-Day Period (Table 2) were plotted as shown in Figure 9. Along with that, the temperature circadian rhythm of each individual was determined and plotted (Appendix C). It is clear from the figure 8 that on average, the participants' temperature is lower early in the morning between 7:30am and 10:00am. After that the temperature continues to increase at a non-steady pace (drops slightly at 5:30) and is highest between 6:30pm to 8:30pm. This shows that there is a common temperature circadian rhythm exhibited by all the participants.

Table 8: Percentage Change in the Average Physical and Mental Performance during High and Low Oral Temperatures

| Average Strength | High Temperature | Low Temperature | % Increase |
|------------------|------------------|-----------------|------------|
| Physical (Kg)    | 21.96            | 20.11           | 9.34       |
| Mental (%)       | 62.37            | 59.73           | 4.61       |

### Physical and Mental Performance at High and Low Temperatures

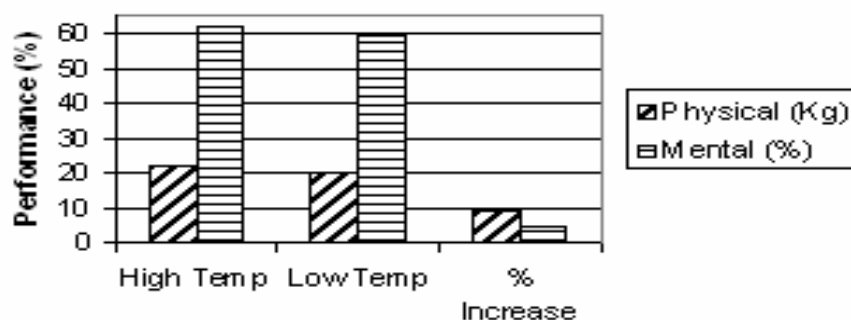


Figure 8. Average Physical and Mental Performance at High and Low Oral Temperatures

### Temperature Circadian Rhythm

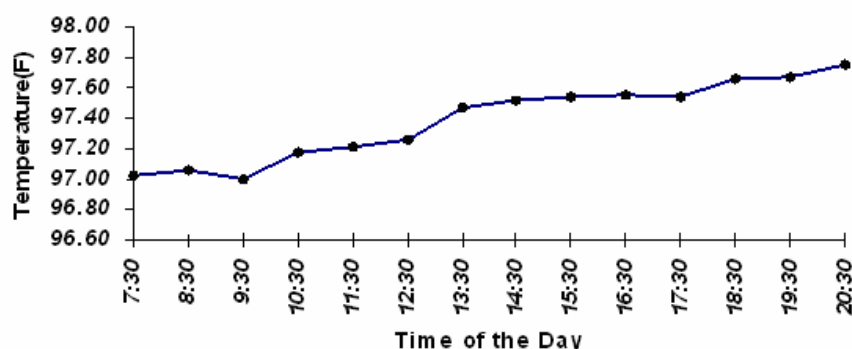


Figure 9. Average Oral Temperature for All Participants Over a 10-day Period

#### 4.2.3 Hypothesis 3

$H_{03}$  = Effect of temperature on male and female performance is the same

$H_{13}$  = Effect of temperature on male and female performance is the same

The data from Tables 4 and 5 were analyzed further to determine whether the effect of temperature on the physical and mental performance was the same or it differed between males and females. It was found that the average change in the physical performance at high and low temperatures for males was 9.38 percent and that for females 9.39 percent which shows there was insignificant difference in the extent to which the physical performance changed in males

and in females. However, the average change in the mental performance at high and low temperatures for males was 4.07 percent and that for females was 5.16. Which shows that female participants were affected slightly more (1.09 percent) than males when it came to mental performance.

#### 4.2.4 Hypothesis 4

$H_{04}$  = Lunar cycle has an impact on individuals' performance

$H_{14}$  = Lunar cycle does not have an impact on individuals' performance

Hypothesis 4 was tested by running a t-test on the data from Tables 6 and 7. The results of the t-test are displayed in Tables 9 and 10. This analysis was conducted by comparing the data acquired on the 8<sup>th</sup>, 9<sup>th</sup>, 10<sup>th</sup>, 14<sup>th</sup>, 15<sup>th</sup>, 16<sup>th</sup>, and 17<sup>th</sup> of June to the 11<sup>th</sup>, 12<sup>th</sup>, and the 13<sup>th</sup> of June individually using t-test. The results showed that at a significance level of  $\alpha=0.05$ , the lunar cycle had no effect on the physical and mental performance of the individuals.

Table 9: Effect of Lunar Cycle on Physical Performance Analysis Using t-test

| 11-Jun   | 12-Jun   | 13-Jun   |
|----------|----------|----------|
| 0.225717 | 0.179120 | 0.258510 |
| 0.397049 | 0.471117 | 0.361745 |
| 0.137450 | 0.143918 | 0.163239 |
| 0.482532 | 0.471677 | 0.494153 |
| 0.292412 | 0.119975 | 0.349792 |
| 0.345167 | 0.256786 | 0.403234 |
| 0.088967 | 0.206479 | 0.226486 |

Table 10: Effect of Lunar Cycle on Mental Performance Analysis Using t-test

| 11-Jun   | 12-Jun   | 13-Jun   |
|----------|----------|----------|
| 0.23264  | 0.46298  | 0.091985 |
| 0.215146 | 0.23811  | 0.053989 |
| 0.343899 | 0.298508 | 0.278245 |
| 0.184523 | 0.305955 | 0.216151 |
| 0.353228 | 0.167241 | 0.218727 |
| 0.309652 | 0.403856 | 0.247666 |
| 0.125306 | 0.342995 | 0.040240 |

## **CHAPTER 5: DISCUSSIONS**

### **5.1 Discussion of the Experiment**

This study aimed at determining the following objectives (1) the effect of temperature circadian rhythm on the mental and physical performance, (2) whether a common temperature circadian rhythm pattern exists for all the participants or each participant has a unique rhythm, (3) the times of the day when the participants perform their best and worst in comparison to their highest and lowest temperatures respectively, (4) the effect of the temperature circadian rhythm on the physical and mental performance is different in males and females, and (5) the effect of lunar cycle on the physical and mental performance.

#### **5.1.1 Effect of Temperature Circadian Rhythm on Performance**

One of the primary objectives of this research was to determine the effect of the oral temperature circadian rhythm on the physical and mental performance of human beings. Literature shows that research has been conducted to see the effect of temperature on Neurobehavioral functioning and cognitive performance. Kenneth *et al.* (2002) studied the relationship between alertness performance and body temperature in humans. The results indicated that within the normal circadian range of body temperature, higher body temperature represented physiological arousal that enhanced neurobehavioral and cognitive functioning involving performance measures such as working memory, subjective alertness, and visual attention.

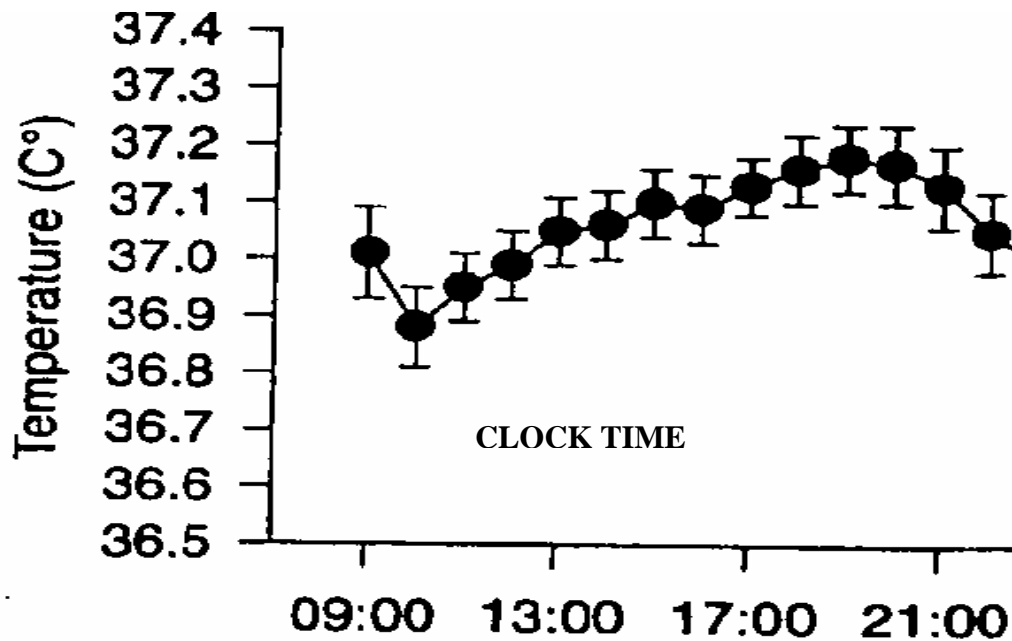
Another study was conducted to see circadian rhythms in human performance. The study suggested that temperature changes may reflect changes in the metabolic processes which could facilitate the performance by speeding up the rate at which information is processed. On average, working memory and cognitive throughput improved by approximately two correct answers as

opposed to none and mental alertness improved by approximately three points (Monk *et al.*, 1997). The findings of the above mentioned research go hand-in-hand with the findings of this research except for the fact that this research, along with the mental aspect of performance, also considered the physical aspect of performance and utilized oral temperature for the study as opposed to the previous studies that utilized rectal temperature. The results of this study showed that on average the physical performance increased by about 9 percent from low body temperature to high temperature and the mental performance increased by almost 5 percent from low temperature to high temperature.

The results to some extent agreed with the studies conducted by Holland *et al.* (1985) who studied the effects of raised body temperature on reasoning, memory, and mood. Their study showed that increase in core temperature was associated with a significant increase in the speed of performance of the tests, by 11 and 10%, respectively. The difference in the results was primarily due to the methods utilized in gathering the data. The study conducted by Holland *et al.* used rectal temperature, where as this study utilized oral temperature. Previous studies showed that ingestion of hot and cold liquids, smoking, and mastication can significantly influence oral temperature measurement for seven to nine minutes following ingestion (Terndrup *et al.*, 1989; Rabinowitz *et al.*, 1996). Since this experimental setup lacked controlled conditions, the temperature readings could have been affected. Controlled setup would include regulation of food consumed by the participants and prohibition of smoking or chewing gum. Another factor that would be regulated in the event that the participant did consume something hot or cold or had to smoke would be to ensure that the participant waits for about 10 minutes before taking his/her temperature to improve the accuracy of the data

### 5.1.2 Exhibition of a Common Circadian Rhythm Pattern

Even though, each participant's high and low temperatures varied to some extent, however, the average temperature circadian rhythm followed a common pattern that can be seen in the Figure 8 below. It is clear from the graph that on average the participant's body temperature over a 13 hour period is low between 7:30am and 9:30am and it starts increasing at a non steady pace (drops slightly around 12:30pm and 5:30pm) afterwards with the highest temperature between 6:30pm and 8:30pm. This graph showed consistency with the findings of the research conducted by Monk *et al.* (1996). Figure 10 shows the temperature circadian rhythm pattern exhibited in Monk's study.



**Figure 10.** Rectal Temperature as a Function of Time (Monk *et al.*, 1996)

It is clear from Figure 10 that the body temperature decreases until about 10:00am and starts increasing gradually after that with highest values between 7:00pm and 8:00pm. It can also be seen that there was slight drop around 4:30pm. Hence, the circadian rhythm patterns for oral and

rectal temperature were consistent. The slight differences, as mentioned earlier, were primarily due to the extraneous factors such as ingestion of hot/cold foods, smoking, possibly mastication (chewing gum) and so on that affect oral temperature.

### **5.1.3 Effect of Temperature Circadian Rhythm on Performance in Males and Females**

One of the objectives of this study was to determine the extent to which the physical and mental performances are impacted by changes in temperature in males and females. There is no literature that examined this criterion. Numerous studies were conducted to see the difference in the physical strength of males and females and even then, the mental aspect was completely ignored. Miller *et al.* (1993) conducted a study on Gender differences in strength and muscle fiber characteristics. The results of their study showed that women were approximately 52% and 66% as strong as the men in the upper and lower body respectively. The men were also stronger relative to lean body mass. Lindle *et al.* (1997) conducted another study on age and gender comparison in muscle strength in middle-aged men and women. The findings of their research suggested that there were age-related reductions in concentric and eccentric peak torque for men and women at but no differences were observed between the gender groups. Age explained losses in concentric better than eccentric peak torque, accounting for 30% (Con) vs. 19% (Ecc) of the variance in men and 28% (Con) vs. 11% (Ecc) in women. Both men and women showed significant declines in muscle quality for Con peak torque but no gender differences were observed. However, the research did not study the mental performance or the degree of affect of temperature on performance in the two genders.

The current study showed that females' physical strength was approximately 45% of that of males which to some extent agrees with the study conducted by Lindle *et al* (1997). However, these results were based on the static arm strength. However, these results were based on the

static arm strength. Other than that, this study determined the extent to which the physical and mental performances are impacted by changes in temperature in males and females, which has not been done in the past. It was found that there was no significant difference in the extent to which the physical performance changed in males and females due to variation in temperature. The average change in the physical performance at high and low temperatures for males was 9.38 percent and that for females 9.39 percent, which shows there was insignificant difference. However, the average change in the mental performance at high and low temperatures for males was 4.07 percent and that for females was 5.16. Which shows that female participants were affected slightly more (1.09 percent) than males when it came to the impact of temperature change on mental performance.

#### **5.1.4 Impact of Lunar Cycle on Performance**

As mentioned earlier, there is a paucity of scientifically documented sources that could provide possible explanation on the impact of full moon on the performance in human beings hence one of the objectives of this research was to determine the possible effect full moon could have on the physical and mental performance in individuals. The results showed that full moon had no impact on the physical and mental performance in individuals.

## **CHAPTER 6: CONCLUSION AND RECOMMENDATIONS**

### **6.1 Synopsis**

This study was conducted to determine if the oral temperature circadian rhythm had an impact on the physical and mental performance of individuals. Further more, the study aimed at determining whether the temperature circadian rhythm of individuals followed a common pattern or each individual had a unique pattern. The experimentation procedure utilized equal number of male and female participants to see extent to which the temperature circadian rhythm affects the performance in each gender. Finally, another dimension was included in the study to determine the effect of lunar cycle, primarily full moon, on the individuals' performance. Before commencing with the experiment, each participant was asked to sign a consent form for ethical purposes and the participants were asked to come in to perform the physical and mental tests three times, at their high temperature, low temperature, and between 12:30 to 1:30pm for the lunar cycle.

### **6.2 Conclusion**

Upon analysis of the data, the following conclusions were reached in conformity with the research objectives:

- The oral temperature circadian rhythm had an impact on the physical and mental performance of individuals. It was concluded that the participants performed better, both physically and mentally, at higher body temperatures. On average, the participants exhibited a common temperature circadian rhythm pattern even though the individual pattern varied to some extent among the participants.
- The body temperature is lowest early in the morning up until 10:30am and is highest between 6:30pm and 8:30pm.

- The average physical performance at high and low temperatures for males and females varied uniformly. However, the average deviation in the mental performance at high and low temperatures for males was about 1.09 percent less than that of females.
- There was no significant impact of the lunar cycle on the performance of individuals.

### **6.3 Future Recommendations**

The following are some recommendations that are strongly suggested for future studies.

- This study utilized a sample size of 10 similar to previous studies conducted by Cagnacci *et al.* (1999) on Melatonin as a major regulator of the circadian rhythm of core temperature in humans and Kenneth *et al.* (2002) on the relationship between alertness, performance and body temperature in humans which utilized a sample size of 7 and 9 participants respectively. However, it is recommended to use a sample size of about 30 to get statistically significant results.
- Rectal temperature by far is the most accurate form of measuring temperature however, it is not always easy to get the measurements for rectal temperature and the next feasible option would be to get the readings by placing the thermometer under the arm since it is not as sensitive to fluctuation as the oral temperature. As mentioned earlier, oral temperature varies significantly by extraneous factors such as ingestion of hot/cold foods, smoking, and mastication. In addition, underarm temperature would be much easier and feasible to measure unlike rectal temperature.
- If oral temperature is utilized in future studies, the external factors such as ingestion of hot/cold foods, and smoking should be taken in to consideration and it should be ensured that the participants do not take the readings immediately after ingestion but wait for

about 15 minutes before taking the temperature since those factors significantly impact the oral temperature.

- It would be ideal if the experiment is conducted in a controlled environment. Controlled setup would include participants in a laboratory setting monitored constantly to ensure that they are taking readings on the designated times under the right conditions. Such conditions would include regulation of hot and cold foods consumed by the participants and prohibition of smoking or chewing gum. In the event that the participant does consume something hot or cold or has to smoke, it would be ensured that the participant waits for about 10 minutes before taking his/her temperature to reduce the risk of flawed data.
- Due to time constraints, this study was unable to utilize the complete lunar cycle, which comprises of four stages; new moon, first quarter, full moon, last quarter. This study did not include the new moon phase or the end phase. It started from the first quarter up until the beginning of last quarter. It is recommended that the data collection days encompass the entire new moon phase and the last quarter along with full moon to provide more relevant data for the research.

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## APPENDIX-A: CONSENT FORM

- Research Project Title: Influence of the Circadian Rhythm on the Physical and Mental Performance.
- Performance Site: Human Factors Laboratory, Louisiana State University, 3412 CEBA.
- Investigator: Dr. Fereydoun Aghazadeh, Phone: (225)-578-5367  
M.S. thesis of: Maryam Muhammed Amin Phone: (225)-276-9195
- Research Purpose: The proposed study focused on the physical and mental performance of participants by determining the following factors.  
1) Effect of oral temperature circadian rhythm on the mental and physical performance.  
2) If a common oral temperature circadian rhythm pattern exists for all the participants or each participant has a unique rhythm.  
3) Times of the day when the participants perform their best and worst in comparison to their highest and lowest temperatures respectively.  
4) If the effect of the temperature circadian rhythm on the physical and mental performance is different in males and females.  
5) Effect of lunar cycle on the physical and mental
- Subject Inclusion: 10 healthy participants (5 males and 5 females) between the ages of 20-28 years will be recruited from Louisiana State University student body.
- Study Procedures: The experiment will be explained to the participants in detail and the participants will be asked to read and sign the consent form. Any question concerning the research will be answered. Participants will be given thermometers to measure their oral temperatures everyday from 7:30 am to 8:30pm for 10 days. The participants' high and low temperatures and the corresponding times will be determined and based on those times, the participants will be asked to come in to the lab twice (at high and low temperatures) to take physical strength tests and mental performance tests. The participants' physical strength will be measured by giving them the static arm pull test using the Dillon Quantrol load cell, which will measure the maximum/peak static force (tension) exerted by the participant. The mental performance test will consist of a set of unbiased questions with simple addition and subtraction problems, Suduko puzzle, and cognitive type questions. Different questions will be used for the high temperature testing and low temperature testing so the participants would not

be able to recall answers which would affect the accuracy of the data.

Risks: The potential risk of participating in the study would be the tendency for the participants to pull their back, neck, or arm muscles due to overexertion. If this study causes any injury to the participants, no insurance is available to cover any injury. Treatment and financial compensation must be provided through the participants' own insurance plan. In case of emergency, the local emergency service will be called.

Participation: Participation in this is voluntary and the participants may change their mind and withdraw from the study at any given time without penalty.

Privacy: The study will be confidential and the data collected will not be identified with participants.

Financial Information: There will be neither monetary compensation nor cost associated with participating in this study.

Personal Data: Age \_\_\_\_\_  
Weight \_\_\_\_\_ Kg  
Height \_\_\_\_\_ cm  
Gender \_\_\_\_\_

“The study has been discussed with me and all my questions have been answered. I may direct any additional questions regarding the study to the investigators. I agree to participate in this study and acknowledge the researcher's obligation to provide me with a copy of this consent form if signed by me”

Participant's Signature \_\_\_\_\_ Date \_\_\_\_\_

## **APPENDIX-B: MENTAL PERFORMANCE TESTS GIVEN AT LOW AND HIGH TEMPERATURES**

### **Low Temperature**

1.  $157 + 326 =$
2.  $284 - 432 =$
3. How many animals of each type did Moses take on the ark?
4. Fill each row and column in the Suduko Puzzle without repeating the number of rows and column.

### **Suduko Puzzle**

|   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|
|   |   |   |   |   | 1 | 8 |   | 9 |
| 7 |   |   |   | 9 |   | 6 |   |   |
| 1 | 8 |   |   |   | 6 |   |   | 2 |
|   | 4 | 8 |   |   |   |   |   | 7 |
| 5 |   |   | 9 |   | 3 |   |   | 6 |
| 6 |   |   |   |   |   | 4 | 3 |   |
| 2 | 6 |   | 8 |   |   |   |   | 4 |
|   |   | 4 |   | 6 |   |   |   | 8 |
| 8 |   | 1 | 2 |   |   | 5 |   |   |

### **High Temperature**

1.  $527 + 291 =$
2.  $958 - 472 =$
3. How many animals of each type did Moses take on the ark?
4. Fill each row and column in the Suduko Puzzle without repeating the number of rows and column.

(Continuation of mental performance test at high temperature)

Sudoku Puzzle

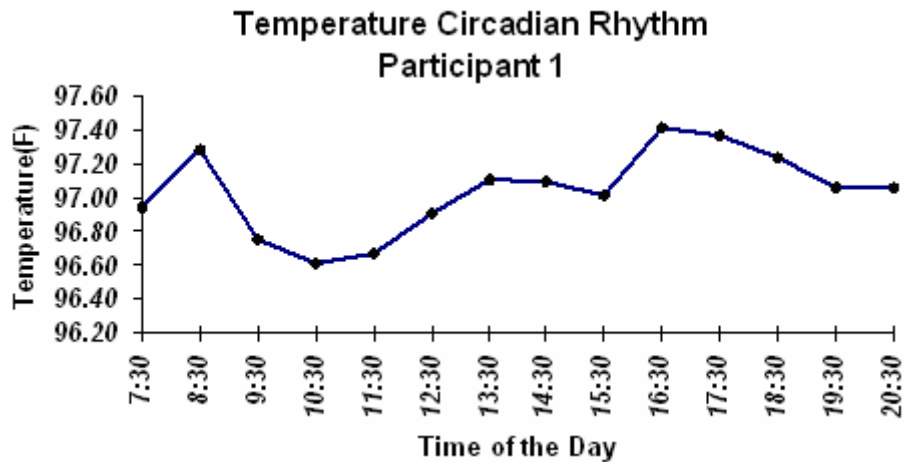
|   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|
|   |   |   |   |   | 2 | 8 |   | 9 |
| 2 |   |   |   | 9 |   |   |   |   |
| 1 | 8 |   |   |   | 6 |   |   | 2 |
|   | 5 | 8 |   |   |   | 2 |   | 7 |
| 5 |   |   | 4 |   | 3 |   |   | 6 |
| 4 | 1 |   |   | 8 |   | 6 | 9 |   |
| 6 |   |   | 8 |   |   |   |   | 3 |
|   |   | 4 |   | 5 |   |   |   | 7 |
| 8 |   |   | 2 |   | 1 |   |   |   |

## APPENDIX-C: AVERAGE HOURLY TEMPERATURE FOR INDIVIDUAL PARTICIPANTS OVER A 10-DAY PERIOD

Average Hourly Temperature for Participant 1 over a 10-Day Period

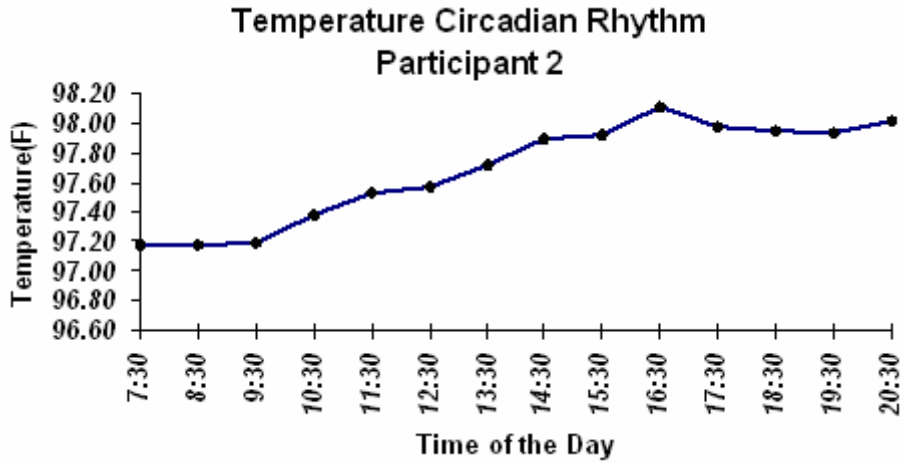
| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>M</b>     | <b>96.94</b> | <b>97.29</b> | <b>96.75</b> | <b>96.61</b> | <b>96.67</b> | <b>96.91</b> | <b>97.11</b> | <b>97.10</b> | <b>97.02</b> | <b>97.41</b> | <b>97.36</b> | <b>97.23</b> | <b>97.06</b> | <b>97.06</b> |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |

Note: Each graph corresponds to the highlighted participant



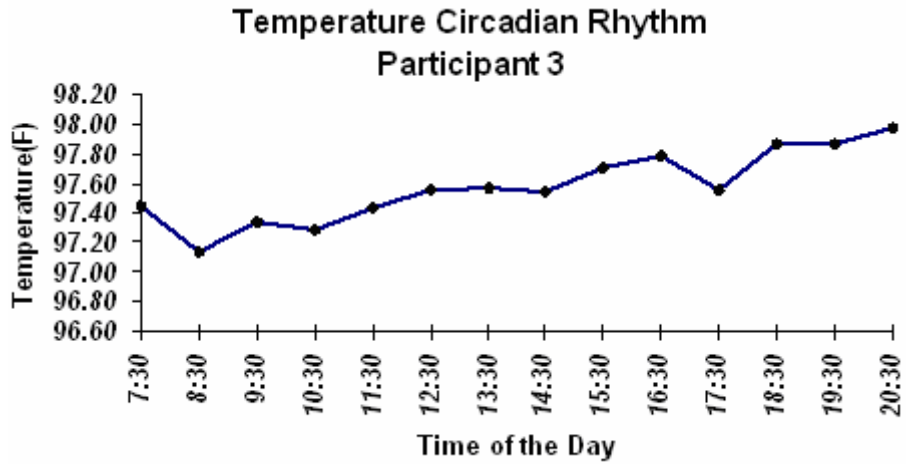
### Average Hourly Temperature for Participant 2 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| <b>M</b>     | <b>97.17</b> | <b>97.17</b> | <b>97.19</b> | <b>97.38</b> | <b>97.53</b> | <b>97.57</b> | <b>97.72</b> | <b>97.89</b> | <b>97.92</b> | <b>98.10</b> | <b>97.97</b> | <b>97.95</b> | <b>97.93</b> | <b>98.02</b> |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



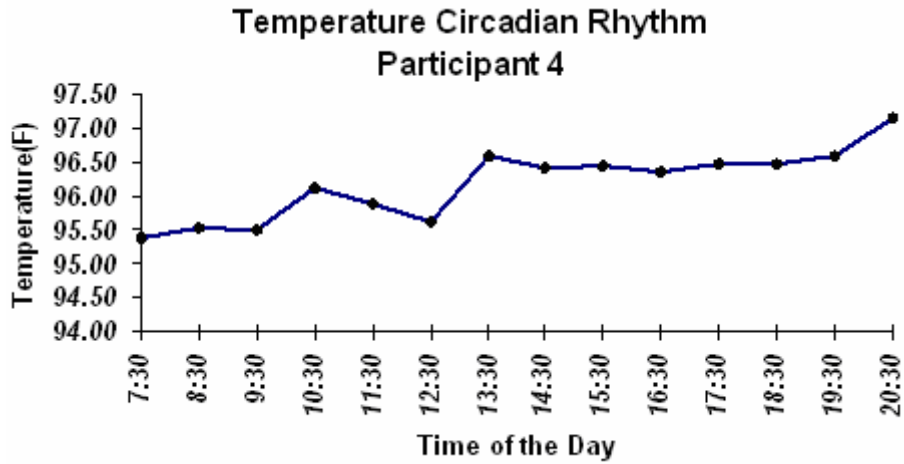
### Average Hourly Temperature for Participant 3 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| <b>M</b>     | <b>97.45</b> | <b>97.13</b> | <b>97.33</b> | <b>97.29</b> | <b>97.43</b> | <b>97.56</b> | <b>97.57</b> | <b>97.55</b> | <b>97.70</b> | <b>97.79</b> | <b>97.56</b> | <b>97.87</b> | <b>97.86</b> | <b>97.97</b> |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



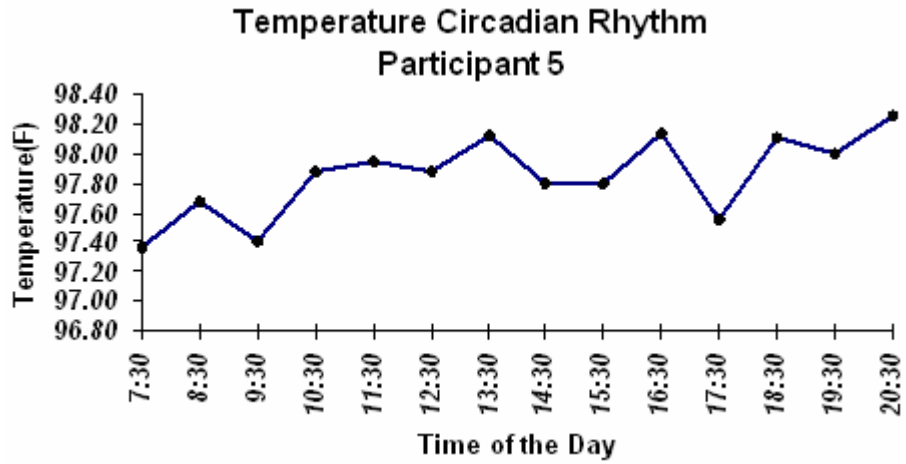
### Average Hourly Temperature for Participant 4 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| <b>F</b>     | <b>95.37</b> | <b>95.53</b> | <b>95.50</b> | <b>96.12</b> | <b>95.87</b> | <b>95.63</b> | <b>96.58</b> | <b>96.42</b> | <b>96.43</b> | <b>96.35</b> | <b>96.46</b> | <b>96.48</b> | <b>96.59</b> | <b>97.14</b> |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



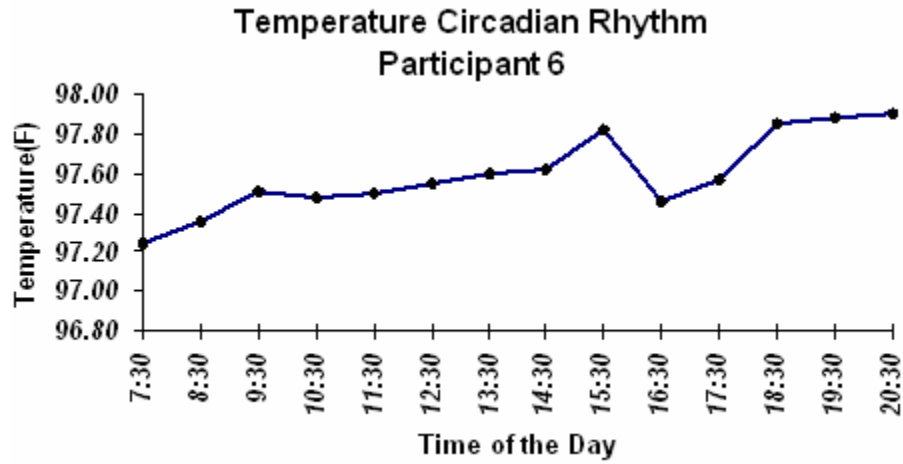
### Average Hourly Temperature for Participant 5 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| <b>F</b>     | <b>97.37</b> | <b>97.68</b> | <b>97.40</b> | <b>97.87</b> | <b>97.94</b> | <b>97.87</b> | <b>98.12</b> | <b>97.79</b> | <b>97.80</b> | <b>98.14</b> | <b>97.56</b> | <b>98.10</b> | <b>98.00</b> | <b>98.25</b> |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



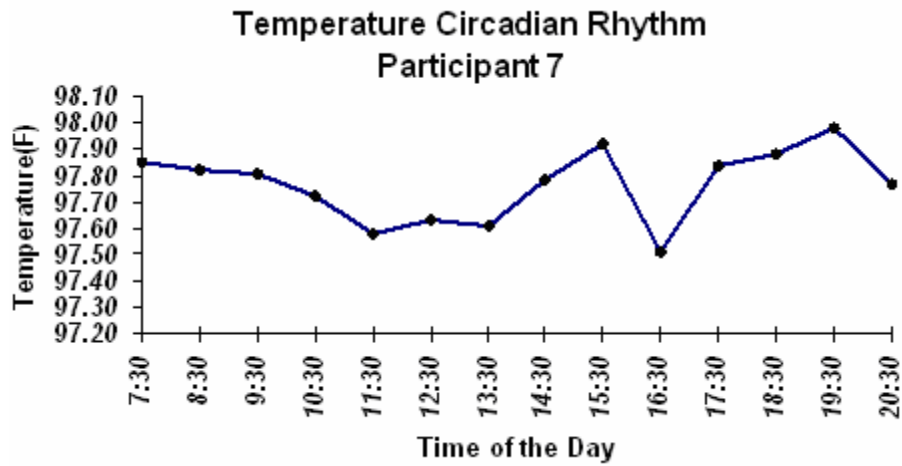
### Average Hourly Temperature for Participant 6 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| <b>F</b>     | <b>97.24</b> | <b>97.35</b> | <b>97.51</b> | <b>97.48</b> | <b>97.50</b> | <b>97.55</b> | <b>97.60</b> | <b>97.62</b> | <b>97.82</b> | <b>97.46</b> | <b>97.57</b> | <b>97.85</b> | <b>97.88</b> | <b>97.90</b> |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58        | 97.63        | 97.61        | 97.78        | 97.92        | 97.51        | 97.83        | 97.88        | 97.98        | 97.77        |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



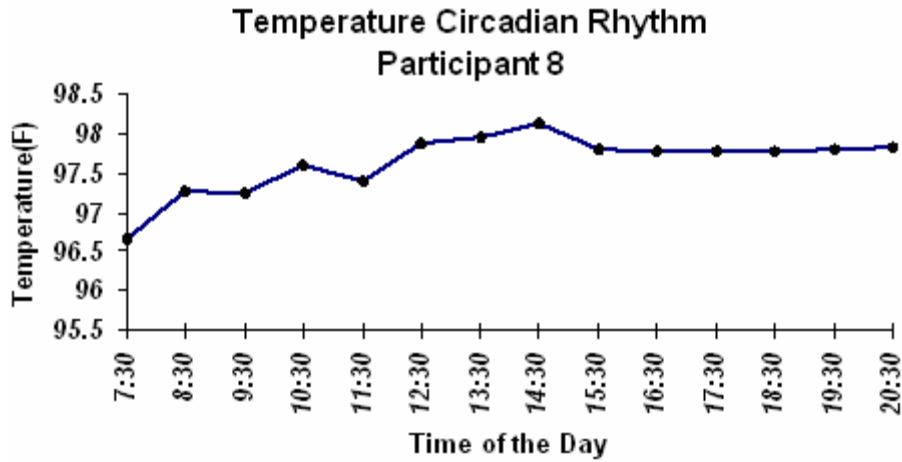
### Average Hourly Temperature for Participant 7 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30        | 12:30        | 13:30        | 14:30        | 15:30        | 16:30        | 17:30        | 18:30        | 19:30        | 20:30        |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67        | 96.91        | 97.11        | 97.10        | 97.02        | 97.41        | 97.36        | 97.23        | 97.06        | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53        | 97.57        | 97.72        | 97.89        | 97.92        | 98.10        | 97.97        | 97.95        | 97.93        | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43        | 97.56        | 97.57        | 97.55        | 97.70        | 97.79        | 97.56        | 97.87        | 97.86        | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87        | 95.63        | 96.58        | 96.42        | 96.43        | 96.35        | 96.46        | 96.48        | 96.59        | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94        | 97.87        | 98.12        | 97.79        | 97.80        | 98.14        | 97.56        | 98.10        | 98.00        | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50        | 97.55        | 97.60        | 97.62        | 97.82        | 97.46        | 97.57        | 97.85        | 97.88        | 97.90        |
| <b>F</b>     | <b>97.85</b> | <b>97.82</b> | <b>97.80</b> | <b>97.72</b> | <b>97.58</b> | <b>97.63</b> | <b>97.61</b> | <b>97.78</b> | <b>97.92</b> | <b>97.51</b> | <b>97.83</b> | <b>97.88</b> | <b>97.98</b> | <b>97.77</b> |
| M            | 96.66        | 97.27        | 97.25        | 97.58        | 97.4         | 97.87        | 97.9         | 98.1         | 97.8         | 97.76        | 97.76        | 97.8         | 97.8         | 97.81        |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97        | 96.73        | 96.9         | 97.4         | 97.4         | 97.45        | 97.78        | 97.8         | 97.9         | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5         | 97.6         | 97.8         | 98.0         | 97.9         | 98.2         | 98.3         | 98.3         | 98.3         | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21        | 97.26        | 97.47        | 97.51        | 97.54        | 97.55        | 97.54        | 97.66        | 97.67        | 97.76        |



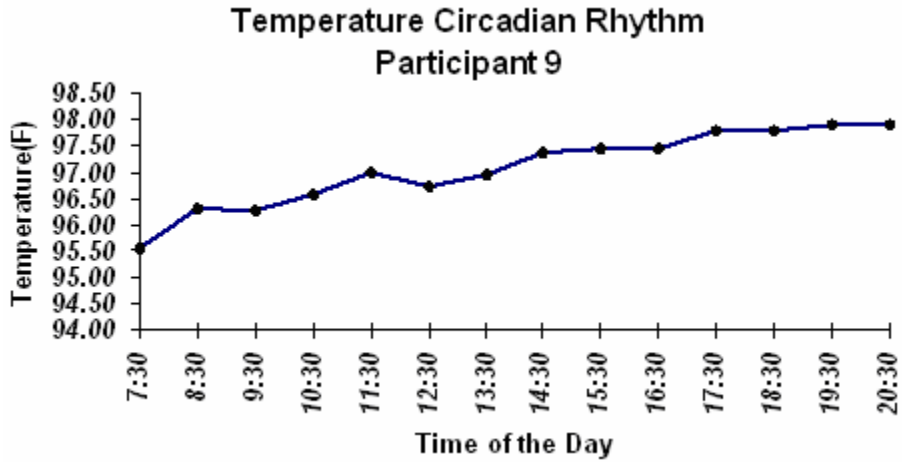
### Average Hourly Temperature for Participant 8 over a 10-Day Period

| Participants | 7:30         | 8:30         | 9:30         | 10:30        | 11:30       | 12:30        | 13:30       | 14:30       | 15:30       | 16:30        | 17:30        | 18:30       | 19:30       | 20:30        |
|--------------|--------------|--------------|--------------|--------------|-------------|--------------|-------------|-------------|-------------|--------------|--------------|-------------|-------------|--------------|
| M            | 96.94        | 97.29        | 96.75        | 96.61        | 96.67       | 96.91        | 97.11       | 97.10       | 97.02       | 97.41        | 97.36        | 97.23       | 97.06       | 97.06        |
| M            | 97.17        | 97.17        | 97.19        | 97.38        | 97.53       | 97.57        | 97.72       | 97.89       | 97.92       | 98.10        | 97.97        | 97.95       | 97.93       | 98.02        |
| M            | 97.45        | 97.13        | 97.33        | 97.29        | 97.43       | 97.56        | 97.57       | 97.55       | 97.70       | 97.79        | 97.56        | 97.87       | 97.86       | 97.97        |
| F            | 95.37        | 95.53        | 95.50        | 96.12        | 95.87       | 95.63        | 96.58       | 96.42       | 96.43       | 96.35        | 96.46        | 96.48       | 96.59       | 97.14        |
| F            | 97.37        | 97.68        | 97.40        | 97.87        | 97.94       | 97.87        | 98.12       | 97.79       | 97.80       | 98.14        | 97.56        | 98.10       | 98.00       | 98.25        |
| F            | 97.24        | 97.35        | 97.51        | 97.48        | 97.50       | 97.55        | 97.60       | 97.62       | 97.82       | 97.46        | 97.57        | 97.85       | 97.88       | 97.90        |
| F            | 97.85        | 97.82        | 97.80        | 97.72        | 97.58       | 97.63        | 97.61       | 97.78       | 97.92       | 97.51        | 97.83        | 97.88       | 97.98       | 97.77        |
| <b>M</b>     | <b>96.66</b> | <b>97.27</b> | <b>97.25</b> | <b>97.58</b> | <b>97.4</b> | <b>97.87</b> | <b>97.9</b> | <b>98.1</b> | <b>97.8</b> | <b>97.76</b> | <b>97.76</b> | <b>97.8</b> | <b>97.8</b> | <b>97.81</b> |
| M            | 95.54        | 96.3         | 96.28        | 96.57        | 96.97       | 96.73        | 96.9        | 97.4        | 97.4        | 97.45        | 97.78        | 97.8        | 97.9        | 97.9         |
| F            | 98.7         | 98.0         | 97.9         | 98.2         | 97.5        | 97.6         | 97.8        | 98.0        | 97.9        | 98.2         | 98.3         | 98.3        | 98.3        | 98.5         |
| Average      | 97.03        | 97.06        | 97.00        | 97.18        | 97.21       | 97.26        | 97.47       | 97.51       | 97.54       | 97.55        | 97.54        | 97.66       | 97.67       | 97.76        |



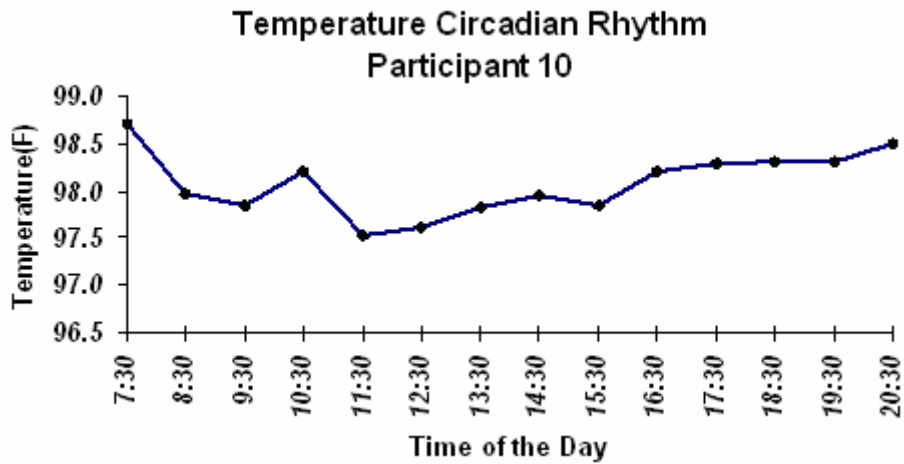
### Average Hourly Temperature for Participant 9 over a 10-Day Period

| Participants | 7:30         | 8:30        | 9:30         | 10:30        | 11:30        | 12:30        | 13:30       | 14:30       | 15:30       | 16:30        | 17:30        | 18:30       | 19:30       | 20:30       |
|--------------|--------------|-------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|--------------|--------------|-------------|-------------|-------------|
| M            | 96.94        | 97.29       | 96.75        | 96.61        | 96.67        | 96.91        | 97.11       | 97.10       | 97.02       | 97.41        | 97.36        | 97.23       | 97.06       | 97.06       |
| M            | 97.17        | 97.17       | 97.19        | 97.38        | 97.53        | 97.57        | 97.72       | 97.89       | 97.92       | 98.10        | 97.97        | 97.95       | 97.93       | 98.02       |
| M            | 97.45        | 97.13       | 97.33        | 97.29        | 97.43        | 97.56        | 97.57       | 97.55       | 97.70       | 97.79        | 97.56        | 97.87       | 97.86       | 97.97       |
| F            | 95.37        | 95.53       | 95.50        | 96.12        | 95.87        | 95.63        | 96.58       | 96.42       | 96.43       | 96.35        | 96.46        | 96.48       | 96.59       | 97.14       |
| F            | 97.37        | 97.68       | 97.40        | 97.87        | 97.94        | 97.87        | 98.12       | 97.79       | 97.80       | 98.14        | 97.56        | 98.10       | 98.00       | 98.25       |
| F            | 97.24        | 97.35       | 97.51        | 97.48        | 97.50        | 97.55        | 97.60       | 97.62       | 97.82       | 97.46        | 97.57        | 97.85       | 97.88       | 97.90       |
| F            | 97.85        | 97.82       | 97.80        | 97.72        | 97.58        | 97.63        | 97.61       | 97.78       | 97.92       | 97.51        | 97.83        | 97.88       | 97.98       | 97.77       |
| M            | 96.66        | 97.27       | 97.25        | 97.58        | 97.4         | 97.87        | 97.9        | 98.1        | 97.8        | 97.76        | 97.76        | 97.8        | 97.8        | 97.81       |
| <b>M</b>     | <b>95.54</b> | <b>96.3</b> | <b>96.28</b> | <b>96.57</b> | <b>96.97</b> | <b>96.73</b> | <b>96.9</b> | <b>97.4</b> | <b>97.4</b> | <b>97.45</b> | <b>97.78</b> | <b>97.8</b> | <b>97.9</b> | <b>97.9</b> |
| F            | 98.7         | 98.0        | 97.9         | 98.2         | 97.5         | 97.6         | 97.8        | 98.0        | 97.9        | 98.2         | 98.3         | 98.3        | 98.3        | 98.5        |
| Average      | 97.03        | 97.06       | 97.00        | 97.18        | 97.21        | 97.26        | 97.47       | 97.51       | 97.54       | 97.55        | 97.54        | 97.66       | 97.67       | 97.76       |



### Average Hourly Temperature for Participant 10 over a 10-Day Period

| Participants | 7:30        | 8:30        | 9:30        | 10:30       | 11:30       | 12:30       | 13:30       | 14:30       | 15:30       | 16:30       | 17:30       | 18:30       | 19:30       | 20:30       |
|--------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| M            | 96.94       | 97.29       | 96.75       | 96.61       | 96.67       | 96.91       | 97.11       | 97.10       | 97.02       | 97.41       | 97.36       | 97.23       | 97.06       | 97.06       |
| M            | 97.17       | 97.17       | 97.19       | 97.38       | 97.53       | 97.57       | 97.72       | 97.89       | 97.92       | 98.10       | 97.97       | 97.95       | 97.93       | 98.02       |
| M            | 97.45       | 97.13       | 97.33       | 97.29       | 97.43       | 97.56       | 97.57       | 97.55       | 97.70       | 97.79       | 97.56       | 97.87       | 97.86       | 97.97       |
| F            | 95.37       | 95.53       | 95.50       | 96.12       | 95.87       | 95.63       | 96.58       | 96.42       | 96.43       | 96.35       | 96.46       | 96.48       | 96.59       | 97.14       |
| F            | 97.37       | 97.68       | 97.40       | 97.87       | 97.94       | 97.87       | 98.12       | 97.79       | 97.80       | 98.14       | 97.56       | 98.10       | 98.00       | 98.25       |
| F            | 97.24       | 97.35       | 97.51       | 97.48       | 97.50       | 97.55       | 97.60       | 97.62       | 97.82       | 97.46       | 97.57       | 97.85       | 97.88       | 97.90       |
| F            | 97.85       | 97.82       | 97.80       | 97.72       | 97.58       | 97.63       | 97.61       | 97.78       | 97.92       | 97.51       | 97.83       | 97.88       | 97.98       | 97.77       |
| M            | 96.66       | 97.27       | 97.25       | 97.58       | 97.4        | 97.87       | 97.9        | 98.1        | 97.8        | 97.76       | 97.76       | 97.8        | 97.8        | 97.81       |
| M            | 95.54       | 96.3        | 96.28       | 96.57       | 96.97       | 96.73       | 96.9        | 97.4        | 97.4        | 97.45       | 97.78       | 97.8        | 97.9        | 97.9        |
| <b>F</b>     | <b>98.7</b> | <b>98.0</b> | <b>97.9</b> | <b>98.2</b> | <b>97.5</b> | <b>97.6</b> | <b>97.8</b> | <b>98.0</b> | <b>97.9</b> | <b>98.2</b> | <b>98.3</b> | <b>98.3</b> | <b>98.3</b> | <b>98.5</b> |
| Average      | 97.03       | 97.06       | 97.00       | 97.18       | 97.21       | 97.26       | 97.47       | 97.51       | 97.54       | 97.55       | 97.54       | 97.66       | 97.67       | 97.76       |



## **VITA**

Maryam Amin was born in Nigeria, West Africa, to Pakistani parents in 1982. She attended Crescent International High School in Kano and eventually took G.C.E London Oxford exam to get her high school diploma. She joined Louisiana State University in 2002 and completed the program for Bachelor of Science in Industrial Engineering in May 2005. She then pursued her degree of Master of Science in 2005 in the same department. She worked as a graduate assistant in the Department of Construction Management and Industrial Engineering.