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The effects of two days of partial sleep deprivation on basketball skill performance

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THE EFFECTS OF TWO DAYS OF PARTIAL SLEEP DEPRIVATION ON BASKETBALL SKILL PERFORMANCE

by

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An Abstract

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Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

This study examined the effect of two nights of partial sleep deprivation (PSD) on basketball skill performance. Subjects (N=12) volunteered for the study, and were all experienced basketball players with at least four years of high school or collegiate basketball experience. All subjects were required to stay awake until 5:30 a.m. at which time they were allowed to sleep for 2.5 hours. Beginning at 8:30 a.m., the subjects filled out a Sleepiness Scale as well as a five-hour history form. At 9 a.m., then again at 2 and 7 p.m., the subjects completed a battery of basketball skill tests (vertical jump, free throws, passing, dribbling, defensive movement, and shooting). The complete sleep loss and test regimen was repeated beginning at 11 p.m. At the completion of testing, subjects had slept only five hours in the previous 60-hour period. Data was analyzed using a 3 x 3 factorial ANOVA with repeated measures for each dependent measure to determine if differences were present between days and times. Interactions between time and day or significant main effects were subsequently analyzed using a Tukey HSD Post Hoc test. A main effect of time was found for the following variables: vertical jump, free throws, passing, and defensive movement. The only significant main day effect was for dribbling with a decrease in performance after one night PSD. Overall, the results showed PSD to have no negative effect on vertical jump, free throws, passing, defensive movement, or shooting. However scores for vertical jump, free throws, passing, and defensive movement improved significantly throughout the course of the day. The present study does not provide any evidence that PSD negatively impacts performance of basketball skills but does support a fairly consistent daily oscillation in these skills. These results

should be interpreted with caution given the delimitation placed on basketball skill assessment by the specific tests used in the study.

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A Thesis Presented to the Faculty of

the School of Health Sciences

and Human Performance

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In Partial Fulfillment of the

Requirements for the Degree

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by

Leigh A. Sears

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School of Health Sciences and Human Performance

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Leigh A. Sears

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Sciences and Human Performance at Ithaca College has been approved.

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INTRODUCTION

Sleep is the period that is popularly recognized as a time when the body restores itself; it is a recovery process for daytime activity (Shapiro, 1981). Both athletes and coaches believe that adequate sleep is essential for peak performance (Mougin, Simon-Rigaud, Davenne et al., 1991) and that performance may be compromised by circumstances that cause athletes to either rise very early or delay bedtime. Incidents such as recent time zone change, anxiety causing insomnia, or the start of an event requiring early rising may compound the stress of physical work with partial sleep loss (Hill, Borden, Darnaby, & Hendricks, 1994; Mougin et al., 1992; Mougin et al., 1991; Shapiro, 1981).

Unfortunately, few studies exist that define the effect of sleep (or sleep loss) on athletic performance (Shapiro, 1981), or motor performance (Holland, 1968). Holland (1968) showed one night of sleep loss had no significant effect upon the speed or accuracy with which a jump or manipulation tasks were performed, but work performance, measured by a cycle work test, showed a significant decrement.

There are several studies on exercise and endurance performance after sleep loss, but findings are often inconclusive or conflicting (Chen, 1991). For instance, Bond et al. (1986) and Plyley et al. (1987) found that sleep loss reduced maximal O_2 consumption (VO_{2max}), while Martin and Gaddis (1981) did not find any change in VO_{2max}. In addition, most previous reports indicate that heart rate at a given work rate was not changed by sleep loss (Symons, Vanhelder, & Myles, 1988) but Bond et al. (1986) reported that exercise heart rates were reduced after sleeplessness. Studies on subjects with one night of total sleep deprivation show deficits on certain tasks, whereas long-term sleep reduction of a few hours per night often results in no deficit in exercise performance (Blagrove, Alexander, & Horne, 1995). A similar study by Reilly and Deykin (1983), showed that partial sleep deprivation (PSD) (2.5 hours of sleep every night over 3 nights) did not affect hand grip, broad jump, rating of perceived exertion during a treadmill run, pulmonary function measures, or endurance capacity. However, anaerobic power decreased as well as two-choice visual reaction time. A more complete review of literature can be found in Appendix A.

While most research has focused on exercise performance, there is little known about the effect of PSD on athletic skill or sport performance. Various circumstances can lead to an athlete or a team being forced to play with less than sufficient rest. Therefore, the purpose of this study was to study the effects of two days of PSD on basketball skill performance.

METHODOLOGY

Selection of Subjects

Twelve female subjects participated in this study (N=12). The subjects ranged from 18 to 22 years of age and volunteered from the population of Marietta College. All subjects were experienced basketball players with at least four years of high school or collegiate basketball. All volunteers were required to read and sign an informed consent form (Appendix B) and complete a Sleep Quality Scale (Appendix C) before participating in the study.

Experimental Design

Two groups of six subjects were formed for the purpose of the study. To minimize any learning effect one group was baseline tested the day before the PSD weekend, while another was baseline tested one week after the PSD weekend. Baseline testing (BL) consisted of the same tests, test order, and test times; however, testing was completed after a typical night of sleep (i.e., without PSD). Prior to either BL testing or the PSD experiment, three practice trials of each test were completed to ensure familiarity with each test.

On PSD test weekend, the subjects were asked to check in to the Marietta College Field House at 11:00 p.m. on Friday night. The subjects engaged in low stimulation activities (i.e., reading, talking, watching movies, playing games) from 11:00 p.m. to 5:30 a.m.. At this point, subjects were allowed to sleep for 2.5 hours. Between waking up and the first test session (PSD-1) at 8:30 a.m., the subjects were able to eat, shower, or just wait. Before testing, the subjects were required to fill out a Sleepiness Scale (Appendix D) and a five-hour history form (Appendix E). At 9:00 a.m. the subjects began the testing procedure by having their body temperature measured orally. The subjects then proceeded individually into a conference room for four tests completed in the following order: hand steadiness, trail making, free recall, and reaction time. Data from these tests are not critical to this study and are not reported in this manuscript. Each subject was then escorted to the gymnasium for the basketball skill testing. Skills tests, which are detailed below, were completed in the following order: vertical jump, free throws, passing, dribbling, defensive movement, and shooting.

After the testing session, the subjects were free to leave the gym and resume normal activities with the exception of sleeping and consuming alcohol/caffeine/tobacco. Subjects were asked to report back at 1:30 p.m. and 6:30 p.m. to repeat the testing procedures. They returned to the testing site at 11:00 p.m. to repeat the entire sleep loss and testing procedure (PSD-2). On their return, they filled out a 24-hour history (Appendix F) as well as a five-hour history form. Cognitive and skill testing were again conducted at 9 a.m., 1:30 p.m., and 6:30 p.m. on Sunday. By the end of the testing session, subjects slept only five hours in the previous 60-hour period. After the completion of the study, the subjects were given a debriefing statement (Appendix G).

Selection of Test

The AAHPERD basketball skill test (1984) was chosen to assess basketball skill. This test was chosen due to its documented ability to test the college level athlete. The test battery consisted of four items: control dribble, passing, defensive movement, and speed shooting. Intraclass reliability coefficients range from R=.82 to .97 for all items. In addition, validity ratings for test items range from R=.65 to .95 (Hastad & Lacy, 1989). These tests are more completely described in Appendix H.

Vertical jump was measured using the one step approach. The subject's standing reach height was obtained by having them stand next to the wall with a piece of tape in their dominant hand. From this position, the subject reached upward as high as possible placing the tape on the wall to mark the standing reach height. Once in the starting position, the subject was instructed to keep one foot in place, while using their other foot to step into the jump. To execute the jump, the subject squatted next to the wall, jumped as high as possible, and marked the wall with a second piece of tape. The height of the jump was measured as the distance between the standing and jumping heights. The final score was the mean of three trials.

Statistical Analysis

Data were statistically analyzed using SPSS for the personal computer. A separate 3 x 3 factorial ANOVA with repeated measure was completed for each dependent measure to determine if any differences were present between days and times. The within subject factors were time (9 a.m., 2 p.m., 7 p.m.) and day (BL, PSD-1, PSD-2). The level of significance was $p < 0.05$. Interactions between time and day, or significant main effects, were subsequently analyzed using a Tukey HSD post-hoc test.

RESULTS

Few studies exist that define the effect of sleep loss on athletic performance (Shapiro, 1981), or motor performance (Holland, 1968). Moreover, the findings regarding exercise endurance after sleep loss are often conflicting (Chen, 1991). Studies on subjects with one night of total sleep deprivation show deficits on certain tasks, whereas long-term sleep reduction of a few hours per night often results in no performance decrement (Blagrove, Alexander, & Horne, 1995). The results of this study, which examine the effects of two nights of PSD on basketball skills, are summarized below. Raw data can be found in Appendix I.

Vertical Jump

Tables J - 1 and J - 2 (Appendix J) show data and analyses for vertical jump. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction ($F = .31$, $p = 0.873$). A main effect for time was found ($F = 6.21$, $p = 0.007$) and a post-hoc Tukey HSD showed significant differences between 9 a.m. and 2 p.m., as well as 9 a.m. and 7 p.m.. The mean score at 9 a.m. was 85.80 cm., and the means for 2 p.m. and 7 p.m. were 88.29 cm. and 89.00 cm., respectively. Vertical jump scores improved throughout the day. No significant differences were found between days indicating no effect of PSD on vertical jump.

Free Throw

Tables J -3 and J - 4 (Appendix J) show data and analyses for free throw. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction ($F = .30$, $p = 0.873$). A main effect for time was found ($F = 4.10$, $p = 0.031$), and a Tukey HSD showed significant differences between 9 a.m. and 7 p.m. The mean score at 9 a.m. was 6.3 free throws made, and the means for 2 p.m. and 7 p.m. scores were 7.0 and 7.2 free throws, respectively. Free throw score improved throughout the day with a significant difference between 9 a.m. and 7 p.m. No significant differences were found between days indicating no effect of PSD on free throw performance.

Passing

Tables J - 5 and J - 6 (Appendix J) show data and analyses for passing. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction ($F = 1.18$, $p = .331$). A main effect for time was found ($F = 14.31$, $p = 0.000$), and a Tukey HSD showed significant differences between 9 a.m. and 2 p.m., as well as 9 a.m. and 7 p.m. The mean for all 9 a.m. scores was 43.6, and the means for 2 p.m. and 7 p.m. scores were 45.4 and 45.7, respectively. Passing scores improved throughout the course of the day with no significant differences between days. Again, PSD therefore, had no noteworthy effect on performance.

Defensive Movement

Tables J - 7 and J - 8 (Appendix J) show data and analyses for defensive movement. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction (F = 1.82, p = 0.141). A main effect for time was found (F = 10.22, p = 0.001), and a Tukey HSD showed significant differences between 9 a.m. and 2 p.m. as well as 9 a.m. and 7 p.m. The mean at 9 a.m. was 12.93, and the means for 2 p.m. and 7 p.m. were 12.6 and 12.40, respectively. The scores for defensive movement improved later in the day. No significant differences were found between days indicating that PSD had no effect on defensive movement.

Dribbling

Tables J - 9 and J - 10 (Appendix J) show data and analyses for dribbling. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction (F = .52, p = 0.719). A main day effect was found (F = 4.77, p = 0.019), and a Tukey HSD showed significant differences between the BL and PSD-1. The mean for BL was 15.9 s and the means for PSD-1 and PSD-2 were 16.8 s and 16.4 s, respectively. Scores were significantly lower for the BL than the PSD-1 trial indicating the first night of PSD hampered dribbling scores, but a second night of PSD caused no further detriment. Unlike most other variables, no significant differences for dribbling were found at the different times throughout the day.

Shooting

Tables J - 11 and J - 12 (Appendix J) show data and analyses for shooting. The 3 x 3 factorial ANOVA with repeated measures showed no significant interaction (F = .65, p = 0.911), and no main effect for time or day was found. Shooting remained consistent throughout the days (means: 9 a.m.= 44.77, 2 p.m.= 45.14, 7 p.m.= 45.69) as well as across the days (means: BL = 45.16, PSD-1 = 45.30, PSD-2 = 45.14).

DISCUSSION

The primary purpose of this study was to measure the effects of PSD on the performance of specific basketball skills including vertical jump, free throws, passing, defensive movement, dribbling, and shooting. Most previous literature focuses on the effect of PSD on aerobic exercise, anaerobic exercise, weight lifting performance, and cognitive tests (Reilly & Deykin, 1983; VanHelder & Radwoski, 1989). No previous study discusses the effects of PSD directly on athletic skill performance. Overall, the results showed PSD had no negative effect on vertical jump, free throws, passing, defensive movement, and shooting. This study, however, found scores for vertical jump, free throws, passing, and defensive movement to change significantly throughout the day.

The significant differences for time within this study were found between the morning (9 a.m.) and the afternoon/evening (2 p.m., 7 p.m.) testing times. Performance of almost all basketball skills peaked at either 2 or 7 p.m. supporting the idea of improved performance rhythms throughout the day. Change in performance during the day probably reflects circadian rhythmicity, which is a documented source of variability in performance (Klein, Hermann, Kuklinski, & Wegmann, 1977). It is well known that most performances rise to a plateau later in the day (Klein, Wegmann, Anthanassenas, Huhlweck, & Kuklinski, 1977), with the majority of athletic records set in the late afternoon or evening (Reilly, 1990). Circadian rhythm dictates peaks in reaction time, nerve conduction velocity, hand/eye and neuromuscular coordination, dexterity, and vigilance. These critical performance variables clearly contribute to the occurrence of optimal athletic performance during the afternoon and early evening (Klein, Wegmann, Anthanassenas, Huhlweck, & Kuklinski, 1976). Much of the variability in the circadian rhythm of given physiological parameters can be attributed to environmental and individual factors that modulate circadian rhythmic phase or amplitude. Several factors that could influence circadian rhythmicity in the performing athlete are workload, motivation, circadian chronotype, psychological stressors, and sleep.

Although PSD might be expected to diminish performance, it had no effect on the selected measures of basketball skill in this study. One explanation is that the skill tests may not have been taxing or long enough to cause the expected effect. The tests lasted only 2-60 seconds and are considered discrete and short term in nature. More complex and difficult psychomotor tasks and tasks of long duration are generally documented to be sensitive to sleep loss (Babkoff, Caspy, & Mikulincer, 1991; Winget, DeRoshia, & Holley, 1985). Holland (1968) performed a study to determine the effect of one night of sleep loss on performance of two short motor tasks (jumping and manipulation) and found no significant effect upon task speed or accuracy. When he studied performance of a more extended nature on a cycle ergometer he found a significant decrement in work. A study performed by Reilly & Deykin (1983) showed PSD (2.5 hours of sleep every night over 3 nights) did not affect hand grip, broad jump, ratings of perceived exercise during a treadmill run, pulmonary function measures, or endurance capacity. However, anaerobic power decreased as well as two-choice visual reaction time. Thus, PSD does not appear to affect gross motor functions that include muscular strength, lung power, and treadmill endurance running. This study concurs with that of Holland's who reported that loss of a single night of sleep had no detrimental effect on the performance of motor skills that were discrete and short term in nature. Detrimental effects in athletic skill performance may result, however, when the test is arduous and long-term in nature.

Even though sleep loss interacts with tasks of long duration to produce decrements in performance, an interesting environment or task can mask physiological sleepiness, while a boring environment or task can unmask it (Babkoff, Caspy, & Mikulincer, 1991).

Only one effect of PSD on skill performance was observed in this present study. A significant decrease in dribbling performance was observed after one night of PSD. According to Holley et al. (1981), a boring or repetitive task providing little stimulation may favor the onset of fatigue and poor performance with sleep deprivation. This is probably due to a decrease in motivation, diminished mental performance, or the occurrence of subjective feelings of fatigue. No significant effect of PSD was found in shooting scores. It was the longest (3 trials, 1 minute each) and most complex test in the battery. This test may have also been the most interesting thereby motivating the subjects and allowing them to perform well despite PSD.

Subjects reported "figuring out" or finding strategies to make the passing and shooting tests easier. During the first few trials of the passing test, the subjects tried to pass the ball so hard that it would come off the wall directly back to them. In later trials, the subjects resorted to a less powerful pass resulting in collecting the ball off one bounce. Future studies of this kind should allow a greater practice time for each test thereby minimizing a potential learning effect. Perhaps a learning effect study with 5 – 7 trials should be performed. In this study, however, we had half the subjects perform BL testing a week after PSD thereby accounting for the impact of learning on performance.

Given the results of this study, a coach could conclude that two nights of PSD has no effect on basketball skill performance. However, as already mentioned, the tests in this study may have been too discrete and short term in nature to uncover any detrimental effects of PSD. According to Wilkinson, Edwards, & Haines (1966), one night of PSD had no effect on the first five minutes of work on serial reaction tests, tests of vigilance and math. However, a clear impairment of performance emerges when the tests are prolonged for 15-40 minutes. A basketball game typically lasts two or more hours with 48 minutes of playtime. Furthermore, a basketball game includes a substantial anaerobic component that is susceptible to the impact of sleep deprivation (Reilly & Deykin, 1983). A more realistic test of game-like conditions may have been differently affected by PSD than the discrete tests used for this study. Wilkinson et al. (1966) concluded that if the duration of performance testing is extended so that it approximates a normal workday, the reduction of sleep of half a single night could produce a significant decrease in efficiency. Therefore, given the testing tools used in the present study, practical application of these results must be made with care.

In conclusion, this study showed very little impact of PSD on short-duration tests of basketball skill. It can also be concluded that athletic performance, measured with these tests, undergoes a fairly consistent and significant daily oscillation. The athlete should be aware that circadian variation in physiological processes results in a window for optimal performance between noon and 7 p.m. Although the present study does not provide any evidence that PSD negatively impacts basketball skills, practical application of these results should be made judiciously.

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Appendix A

REVIEW OF LITERATURE

Introduction

To provide background on the study of the effects of sleep deprivation on athletic performance, this review will examine the following topics: (a) sleep, (b) sleep deprivation, (c) sleep deprivation and performance with sleep deprivation, (d) circadian rhythms, (e) circadian dysrhythmia, and (e) physiology and performance.

Sleep

Sleep is a part of daily life and is generally considered a restorative process for the function of the central nervous system (CNS) (Chen, 1991; Shapiro, 1981). The sleep-wake cycle in humans is reflected in the habits of the majority of the population that sleeps at nighttime and works in the daylight hours (Reilly, 1990). Sleep is divided into five distinct stages. Stages one through four constitute non-rapid eye movement (non-REM) sleep. Stages three and four are characterized by EEG waves that have high amplitude and a slow frequency and are referred to as slow wave sleep (SWS). Stage five, rapid eye movement (REM) sleep, is thought to occur after the first three hours of sleep (Wilkinson, Edwards, & Haines, 1966). REM and non-REM sleep repeat in cycles of approximately 90 minutes throughout the night, depending on variables such as age and amount of prior sleep (VanHelder & Radomski, 1989).

Most studies report that SWS serves in the restorative processes for physical fatigue and REM sleep restores the function of the CNS (Mougin et al., 1992). It had also been well documented that athletes' sleep patterns are different from sedentary subjects, with greater amounts of SWS necessary for physical recovery (Mougin et al., 1992).

Sleep Deprivation

Anyone who has stayed awake for more than 24 hours can identify with several subjective effects of sleep deprivation (SD), such as increased sleepiness, mood changes, decreased vigilance, and decreased accuracy in performance of cognitive tasks (VanHelder & Radomski, 1989). Partial sleep deprivation (PSD) or disrupted sleep is a problem more common than total sleep loss, and is also a common source of stress among both athletic and non-athletic populations. Sleep deprivation readily results in psychological changes that are often dramatic (Martin & Gaddis, 1981).

The effects of SD on mental and psychomotor performance are relatively well documented with performance decrements depending on factors such as the complexity and duration of the task, the motivation of the subject, and the interactions with environmental variables (Reilly & Piercy, 1994). Generally, deterioration in mental performance is noted after one night of sleep loss, while gross motor performance can be reasonably well maintained under conditions of PSD (Reilly & Piercy, 1994). However, Johnson and Naitoh (1974) reported difficulty in finding studies demonstrating a consistent performance deficit during short periods of SD. The authors found that an important source of variance in PSD studies is due to a circadian effect. Whether going to bed later, getting up earlier, or by fragmentation of sleep, an alteration occurs in the timing of the sleep-wake cycle. Because of this alteration it is difficult to determine if changes observed following PSD are due to short sleep, or simply to the disruption of sleep (or wakefulness) which disrupts the circadian rhythm. Subsequent to changes in both sleep times and sleep/waking cycles, disruption of the circadian cycle may be more relevant to waking behavior (performance and subjective mood) than PSD (in: Holley, Winget, DeRoshia, Heinold, Edgar, Kinney, Langston, Markley, & Anthony, 1981).

Sleep Deprivation and Performance

Published studies on SD and physical performance are contradictory and often incomparable (VanHelder & Radomski, 1989). A paradoxical finding in studies of PSD is that some tasks show an improvement. Hand steadiness, for example, is better after loss of sleep (Reilly, 1990). This is attributed to a decrease in spontaneous contraction of involved muscles due to reduced muscle tone. Similarly, tasks with high loading on short-term memory appear to improve with SD due to a tendency to code information acoustically for mental storage and recall in laboratory tests (Reilly, 1990).

Some evidence suggests that decreased performance following SD is a function of the complexity of the tasks involved and the time required to complete the tasks (Holland, 1968). It has been argued that the greater the physiological sleepiness the more dependent we become on the environment to maintain wakefulness. An interesting environment or complex task can mask physiological sleepiness, while a boring environment or task (i.e., standard cognitive test) can unmask it (Babkoff, Caspy, & Mikulincer, 1991). A boring or repetitive task would provide little stimulus and favor the onset of fatigue. This would be accompanied by a decrease in motivation, physical and mental performance, and the occurrence of subjective feelings of fatigue (Holley et al., 1981).

Fatigue

Fatigue is often defined as a generalized response to stress (or a defense reaction to stress) over a period of time, which may be either acute and/or chronic, and is measured by performance decrements and reports of subjective feelings (Holley et al., 1981). Anxiety may also be a factor in both acute and chronic fatigue. As Holley et al. (1981) reported, many of the performance decrements in fatigue studies were consistent with high levels of arousal. Both stress and fatigue are important contributors to performance decrement. The most common symptoms of fatigue reported are decreased attention, slowed and impaired perception, impairment of thinking, and a decrease in motivation and physical performance (Holley et al., 1981).

<u>Motivation</u>

Another factor that serves to modify the influence of sleep loss on performance is the motivation of the subject (Reilly & Deykin, 1983). Since it is well established that mood deteriorates with SD, the level of subject motivation may also decline as the period of sleep loss increases. This effect might influence the outcome of physical performance tasks in which motivation plays a key role (Symons, VanHelder, & Myles, 1988). Reilly and Piercy (1994) examined the effects of a reduced ration of sleep on weight lifting performance. The authors found that in tasks requiring a high level of motivation a deterioration in mood states contributed to the decline in maximum weight lifted. The greatest decline occurred in performances that employed larger muscle groups.

The inability to maintain a high level of physical performance during SD can be attributed primarily to psychological fatigue as evidenced by increased ratings of perceived exertion despite unchanged heart rates (Holland, 1968). In Holland's opinion, it appears that athletes do not have to be concerned about their physical performance following a sleep loss of one or even two nights if they are sufficiently motivated. Holland (1968) concluded that the loss of a single night of sleep had no detrimental effect on the performance of motor tasks which were discrete and short term in nature. However, detrimental effects of one night SD occurred in performances that were arduous and prolonged in nature.

An earlier study done by Wilkinson, Edwards, and Haines (1966) suggested that if the duration of performance testing was extended to approximate a normal day of work, the reduction of sleep by half of a single night would produce a significant decrement in working efficiency. The authors claimed that previous studies failed because the performance tests were too short. One night of SD had no effect on the first five minutes of work on serial reaction, vigilance, and tests of addition. A clear impairment of performance, however, emerges when these tests are prolonged for 15-40 minutes. Tasks of long duration interact with SD to produce greater decrements in performance (Babkoff, Caspy, & Mikulincer, 1991).

Sleep loss may make subjects less attentive on elements of a perceptively easy task. Webb (1985) has shown that SD has a greater effect on attention and persistence measures than on cognitive and precision tasks. Another explanation of the effects of sleep loss on tasks requiring the filtering of irrelevant stimuli is that sleepiness simply leads to a subject's declining motivation and a lack of interest in the task at hand, rather than to actual attention deficits (Blagrove, Alexander, & Horne, 1995). However, Blagrove, Alexander, & Horne (1995) have shown that SD subjects lose the capacity, rather than the willingness to perform.

Circadian Rhythms

The daily rhythms that govern much of our physiology and performance are known as circadian rhythms, from the Latin 'circa dies' meaning "about a day". Most physiological functions exhibit circadian rhythmicity which have maximum and minimum functions that occur at specific times of the day. In humans, circadian rhythms are expressed by oscillations in physiological systems (e.g., body temperature, heart rate, and hormone levels) responding to either internal or external stimuli. Circadian rhythms are normally synchronized by periodic alterations in the environment. The primary synchronizers for humans are light-dark cycle alterations and periodic social contact or interaction (Holley et al., 1981).

There are two aspects of circadian rhythmicity that are of importance to the performing athlete. One aspect is the time-dependent alteration in the levels of physiological processes, expressed as circadian range or circadian amplitude (change from daily mean level to the peak of the rhythm) (Walker, Winget, & Soliman, 1981). The other aspect of circadian rhythmicity relating to performance is the effect of rhythm disruption on performance following trans-meridian flight or timing of the normal sleep-wake cycle. Such circadian rhythmic disturbances, which result from shifts in environmental time cues, often result in fatigue, insomnia, sleep disturbances, gastrointestinal complaints, headache, irritability, and reduced performance efficiency (Beljan, Rosenblatt, Hetherington, Lyman, Flaim, Dale, & Holley, 1972).

Circadian rhythm is a major source of variability in performance and the range or amplitude increases with increasing task complexity (Klein, Hermann, Kuklinski, & Wegmann, 1977). Because performance is influenced by factors such as arousal and motivation, performance rhythm variables exhibit higher intra-subject variability than physiological variables. Most performance rhythms rise to a plateau between 1200-2100 hours and then decline to a minimum at 0300-600 hours (Klein, Wegmann, Anthanassenas, Hohlweck, & Kuklinski, 1976). Circadian rhythm peak times for reaction time, nerve conduction velocity, hand/eye and neuromuscular coordination, dexterity, and vigilance clearly contributes to the occurrence of optimal athletic performance during the afternoon and early evening.

Tests carried out using a number of different tasks confirm that human performance varies in a daily rhythm. Athletic performance that occurs several hours before or after the circadian peak "window" will be potentially subject to less than optimal performance efficiency. Also, the sensitivity of the body to drugs such as caffeine or medications is quite different at one time of day versus another, which may also influence subsequent performance (Walker, Winget, & Soliman, 1981).

Temperature

The circadian rhythm in performance was originally thought to be the consequence of the circadian body temperature (Kleitman, 1963). It is more likely that body temperature and performance are not causally related but are independently controlled by a common biological oscillator and that performance rhythm peak times differ because the physiological processes underlying the different performance tasks have different circadian phase relations (Rutenfranz & Colquhoun, 1979). The accepted explanation of these results invokes a theory that asserts there is a circadian rhythm in arousal (or the inverse of sleepiness), showing a rise over the waking day with an early evening peak and thus broadly paralleling the circadian rhythm in body temperature (Monk, 1982). An alternative view is that performance rhythms are the consequence of rhythmic changes in arousal rather than body temperature. In this model, changes in performance are modulated by the inverted "U" relationship between performance and arousal (Monk, 1982). With this model, the complexity of the task determines an optimal arousal level above which performance starts to deteriorate rather than improve. The optimal level is low for high memory load tasks, and high for low memory load tasks (Monk, 1982).

The normal diurnal variation of body temperature is roughly .5° C. The minimum is reached between 0500 to 0600 hours and peaks around 1600 hours (Reeve & Fischman, 1995). The optimal temperature for performance is 38.3 ° C (Winget, DeRoshia, & Holley, 1985). During 40 hours of SD, oral temperatures have been reported to follow a normal circadian pattern with a peak in the late afternoon and a trough in the early morning (VanHelder & Radomski, 1989). In fact, core temperature maintains circadian variation with over 130 hours of sleep loss. The only effect of SD may be an overall lowering of the mean daily oral temperature (VanHelder & Radomski, 1989). The majority of athletic records are set in the late afternoon or evening, close to the time that body temperature is at peak (Reilly, 1990).

Metabolism

Circadian rhythms in metabolism are considered important potential sources of variation in athletic performances. Body temperature directly influences metabolic rate and energy production, and thermoregulatory rhythms control the rate of heat production and removal from the body. The body temperature rhythm has significant effects upon nerve conduction velocity and metabolic enzyme reaction rates, and is highly correlated with psychomotor performance (Fort, Gabbay, Jackett, Jones, Jones, & Mills, 1971).

Circadian variation in capacity to mobilize high energy chemical substrates from glycogen reserves and plasma would be important for the athlete performing at high levels of aerobic activity. The circadian rhythm for plasma insulin peaks during mid-afternoon, and for plasma glucagon peaks during the early evening (Reinberg, Apfelbaum, Assam, & Lacatis, 1974). Overall rhythmic changes in energy metabolism are presumably related to circadian rhythms in secretion of growth hormone, insulin, glucagon, and cortisol secretion, among others (Conlee, Rennie, & Winder, 1976; Dobrzanski, Zurowski, & Graban, 1979; Reinberg, 1983). However, circadian rhythmicity in metabolic substances are largely determined by the exogenous influences of meal constituents and meal timing (Graeber, Gatty, Halberg, & Levine, 1978; Reinberg, 1983). These factors are probably more important in determining time of day effects upon metabolism than the endogenous circadian variation in these substances (Winget, DeRoshia, & Holley, 1985). Most reports agree that short-term SD (<48 hours) has little effect on resting metabolic rate, respiration, blood glucose concentration, or hematocrit. However, acute sleep loss is associated with elevated resting lactate concentrations and reduced heart rates (McMurray & Brown, 1984).

"Postlunch dip"

There is a characteristic drop in performance around lunch time (1200-1400 h), known as postlunch dip as observed in several (Blake, 1967; Kleitman, 1963; Rutenfranz, & Colquhoun, 1979), but not all studies (Folkard, 1983). There is no corresponding drop in the body temperature circadian rhythm during this time (Froberg, 1977). It is unclear whether this performance drop is linked to digestive processes or is characteristic of circadian rhythm (Folkard & Monk, 1983). According to Blake (1967), the postlunch dip is independent of meal time. Kleitman (1963) suggested that it may reflect a modulation of the circadian rhythm levels by an underlying 90 minute rest-activity rhythm or some other 12 hour rhythm. The postlunch dip is more pronounced when work begins earlier in the day (Hildebrandt, Rohmert, & Rutenfranz, 1974), and is associated with a corresponding drop in epinephrine levels (Froberg, 1977). This may result from a transient increase in fatigue or decrease in arousal. The athlete should be aware of the possible impact of the postluch dip on afternoon performance and that the magnitude of the postlunch dip may be increased by fatigue or sleep loss (Winget, DeRoshia, & Holley, 1985).

Cardiac/Vascular Function

Circadian variation in cardiac and vascular function may significantly impact athletic performance because these variations influence: 1) the rate of delivery of oxygen, glucose, and hormones to the various organ systems; 2) the removal of metabolites from these organs; 3) the distribution of metabolic heat from the core to the periphery; and 4) the relative impact of physical exertion upon cardiovascular function itself. Circadian rhythms in cardiac function (stroke volume, cardiac output, and heart rate) peak around 1030-1700 hours (Winget, DeRoshia, & Holley, 1985).

Investigations of the physiological responses of individuals at rest after SD indicate a minimal effect on heart rate, blood pressure, or body metabolism (Sawka, Gonzalez, & Pandolf, 1984). Other investigations have examined the effects of SD on physiological responses to physical exercise. Compared with control levels, SD does not alter heart rate, blood pressure, and oxygen uptake responses during submaximal exercise. However, submaximal exercise time to exhaustion is significantly decreased after SD (Sawka, Gonzalez, & Pandolf, 1984).

In a study conducted by Martin and Gaddis (1981), sleep loss left VO_{2max} unchanged, but decreased peak exercise heart rate. These results were consistent with some previous studies showing that neither resting or exercise heart rates were reduced after SD (Holland, 1968; Pickett & Morris, 1975). Although the factors that regulate exercise heart rate are not fully understood, it is accepted that there is a shift from parasympathetic to sympathetic dominance as work load and heart rate increase. The relative bradycardia after sleep loss, primarily evident at heavier workloads, points to sleep loss as either an activator of parasympathetic, or suppressor of sympathetic activity of the heart during exercise.

Cognitive Function

Circadian rhythms are present in several tasks involving cognitive function. These performances tend to peak earlier in the day than the sensory motor or psychomotor tasks (Folkard & Monk, 1979). Also, according to Doring & Reicke (1952) long term memory recall (one week) is eight percent higher when the material is presented at 1500 hours compared to 0900 (in Smolensky, Tator, & Burgman, 1976). This may have implications for the timing of coaching instructions and strategy, since the eight percent difference in memory retention is similar to the decrement induced by restriction to three hours of sleep (Folkard, Monk, Bradbury, & Rosenthal, 1977).

Personality Factors

There is some evidence that the phasing of circadian rhythms is affected by personality (Reilly, 1990). There is a difference of only 65 minutes in the body temperature rhythm peak times between morning and evening types, but morning types secrete significantly more epinephrine in the morning than evening types. The timing of mood and activity rhythms differs by several hours between distinct morning and evening types (Blake & Corcoran, 1972). The actual circadian rhythmic performance level for a given athlete is determined by the chronotype of the individual athlete relative to the time of day at which the event is performed (Winget, DeRoshia, & Holley, 1985). Introverts tend to be better performers in the morning whereas extroverts are more sluggish at this time. Extroverts make up for this by reaching a peak level of performance later in the day than do introverts, and stay alert longer in the evening (Reilly, 1990).

The morning performance superiority of people with morning chronotypes disappears when subjects perform in close visual contact. Social interaction between individuals also has an important role in mutual circadian rhythm synchronization. Adverse social interaction between isolated group members may be associated with an increased tendency for group rhythm dissociation and may precipitate individual internal rhythmic desynchronization. Social interaction between athletes may not only impact performance levels in terms of positive (well-being, motivation) or negative (psychological stressors) psychological factors but may also affect performance through positive (rhythm synchronization) or negative (desynchronization) effects upon circadian rhythmicity (Winget, DeRoshia, & Holley, 1985).

Circadian Dysrhythmia

Nearly all physiological functions undergo regular changes from day to night. These diverse rhythms keep distinct phase relationships to each other representing a high degree of temporal order known as internal synchronization. Unlike exogenous rhythms, which directly respond to a physical change in the environment, endogenous rhythms persist under conditions lacking environmental time cues. The persistence of endogenous physiologic rhythms is not a learned conditioned response but a function of one or more physiological driving mechanisms referred to as oscillators. Circadian oscillators under natural conditions are synchronized or entrained to a period length of 24 hours by periodic environmental stimuli or Zeitgebers (Holley et al., 1981).

Circadian dysrhythmia is a demonstrable physical, physiological, or psychological deficit associated with internal circadian rhythm disturbance and results from alterations in sleep-wake timing. There is considerable individual variation in the effects of circadian dysrhythmia and time necessary for readaptation. In addition, for a performance rhythm, a complex task exhibits a slower rate of adjustment than a simple one. Circadian dysrhythmia may induce substantial deterioration in performance and well being in susceptible athletes (Wingate, DeRoshia, & Holley, 1985). Factors determining individual susceptibility, such as circadian chronotype, rhythm amplitude, personality, and age may be of use in predicting which individuals may suffer the greatest performance deterioration following phase shift. Available evidence indicates that athletic performance involving dynamic muscle strength, endurance, and vigilance exhibit greater deterioration as a result of circadian dysrhythmia than performance involving isometric strength, simple reaction time, and simple psychomotor function (Winget, DeRoshia, & Holley, 1985).

Exercise Physiology and Sleep Deprivation

In general, the change in physiology with SD is unclear. There have not been many studies that included physiological measurements (Martin & Gaddis, 1981). One study to include physiological measures found that the ability to regulate body temperature was not reduced by sleep loss and concluded that despite considerable psychomotor impairment during SD, physiological regulatory mechanisms were relatively unaffected (Holley et al., 1981). Martin and Gaddis (1981) found that acute 30-hour sleep loss failed to change VO_2, VCO_2, V_E, or heart rate during either mild, moderate, or heavy submaximal exercise. Sleep loss also failed to alter VO_{2max} though it reduced peak exercise heart rate. McMurray and Brown (1984) found no effect of sleep loss on VO_2 during the first three minutes of exercise recovery (i.e. the fast recovery component), however, significantly greater oxygen uptake during the slow component of recovery (minutes 3-15) was found in this study. Sleep loss also significantly increased ratings of perceived exertion (RPE) during moderate and heavy exercise.

Subjective RPE, measured by the Borg scale, appear to be one of the few physiologically related parameters consistently affected by SD (Myles, 1985). Martin and Gaddis (1981) reported that periods of SD lasting from 30-36 hours increased RPE for submaximal exercise. Sleep loss significantly elevates the RPE during exercise despite unchanged heart rate or metabolic rate (Martin, 1981). When the exercise period is as short as 30 seconds, SD has no effect and physical fatigue causes very little change in the perception of intensity (Myles, 1985).

These studies agree that short-term submaximal performance at 75% of maximal capacity or less is not attenuated by sleep loss. Even SD of 64 hours, as long as the exertion was not exhaustive (e.g. 75% or less), had no effect on exercise tolerance (McMurray & Brown, 1984). However, Martin (1981) noted that the time to exhaustion during walking at 80% maximal capacity was reduced.

The mechanisms by which sleep loss decreases exercise tolerance during exhaustive exercise (e.g., 80%) in normal persons remains incompletely defined. One obvious possibility is that sleep loss might alter $VO_{2\ max}$, radically reducing the ability to perform (Martin, 1981). However, as stated, $VO_{2\ max}$ is unchanged by SD (Martin & Gaddis, 1981).

The absence of obvious changes in either the relative use of carbohydrate and non-carbohydrate fuels, or in the total energy cost of exercise, suggests that metabolic factors are not responsible for any reduction in exercise tolerance after sleep loss. The available evidence suggests that perceptual changes may be responsible for decreased endurance tolerance. A study by Morgan (1973) indicates that altered psychological states, such as neurosis, anxiety, and depression, tend to be associated with inaccurate assessment of the severity of exercise. Perceptual changes induced by SD may be largely independent of the usual physiological cues.

Summary

Athletic performance does not occur with respect to fixed physiological functions but instead undergoes significant daily oscillations under the control of a rhythmic pacemaker system (the human circadian system). The athlete should be aware that circadian variation in physiological processes results in a time "window" for optimal performance between 1200 and 2100 hours. The optimal athletic performance for a given event will depend upon the relative importance of each physiological system contributing to the performance, since different systems (e.g., metabolic, neuromuscular) have component rhythms that peak at different times within the 1200-2100 hour distribution of rhythm peak times. The athlete should be aware of factors such as physical and psychological stressors, motivation, ambient temperature, and the postlunch dip, which can alter circadian rhythm and the timing of many physiological variables and subsequently alter performance at a given time of the day.

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APPENDIX B

Informed Consent Form

Purpose of the Study

The purpose of the study is to determine whether partial sleep deprivation, defined as 2 ½ h of sleep for two consecutive nights, has any impact on the performance of sport specific basketball skills during various times of the day. The study will also attempt to determine if a person's preference for a.m. or p.m. performance has any effect on sport skills after partial sleep deprivation.

Benefits of Participation

You will gain an understanding of how changes in your sleeping routine may affect your athletic performance. If a relationship is found between skill performances and cognitive measures, as related to partial sleep deprivation, you may decide to adhere to a particular sleep schedule that will help to optimize your athletic/academic potential. By determining your individual preference for "morningness / eveningness", you will learn of your optimal performance hours. The scientific as well as the athletic community will be informed of the effect that 2 nights of consecutive partial sleep deprivation may have on athletic performance.

What You Will Be Asked To Do

Today, you will be given a sleep quality and a "morningness / eveningness" questionnaire to fill out so I can later determine your individual type. You will also be assigned to 1 of 2 groups and will receive a schedule of test dates in a calendar form. Throughout this study, you will be required to keep a sleep log as to how many hours each night you sleep and if it is quality sleep. This sleep log will be handed in at the final 7:00 p.m. (Sunday) testing session.

Baseline testing will take place either before the sleep deprivation weekend or after the sleep deprivation period starting at 8:15am depending on your scheduled group time. Please refrain from using any alcohol/tobacco/caffeine products 24h prior to this testing session. Upon entering the Marietta College gymnasium, you will receive a pinnie with the last five digits of your social security number written on it. Throughout the study, this pinnie will be collected at the end of each testing session and will be given out at the beginning of each session. This will be used as identification instead of names. At 9:00 a.m., 2:00 p.m., and 7:00 p.m., you will fill out the Stanford Sleepiness scale, take a cognitive test, use a thermometer to get oral temperature readings, and perform a reaction time test, along with sport-specific basketball skill tests. Skills include vertical jump, shooting, passing, dribbling, defensive movement, and free throws. After this set of tests, you will be free to leave the testing site until 2:00 p.m. and 7:00 p.m. respectively, to resume you normal activities as long as you do not fall asleep, or use alcohol/caffeine/tobacco products until after the 7:00 p.m. testing session. Please arrive at the testing site ½ h prior to the test start time.

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Initial Here

After baseline testing, you will return to the Athletic Field House located on the Marietta College campus at 11:00 p.m. on Friday the weekend you are assigned to undergo **two nights of partial sleep deprivation**. Please try to obtain at least 8 h of sleep the Thursday prior to your testing session while sleeping no later than 8:00 a.m. You may bring with you any items necessary to ensure your comfort and maximum participation throughout the testing period (i.e. toothbrush, shower supplies, pillow, magazines, change of clothes, sneakers, etc.). Beverages and light snacks will be provided (upon request). You will be engaged in low stimulation activities such as reading, talking with your groups, playing games, or watching movies from 11:00 p.m. until 5:30 a.m. when you will be asked to go to sleep (on cots that are provided) for a period of 2 ½ h at which time you will be awakened. Between wake up and the first test session at 8:30 a.m., you can take a shower, eat, or do as you please. At 9:00 a.m., you will undergo the same protocol as outlined in the baseline testing session. After the session is over, you may leave the testing site and resume normal activities with the exception of sleeping and consuming alcohol/caffeine/tobacco. Please return ½ h prior to the 2:00 p.m. session and ½ h prior to the 7:00p.m. session. After the Saturday 7:00 p.m. session, you are again free to leave with the same stipulations as outlined previously and are asked to return at 11:00 p.m. on Saturday night to undergo the same testing procedures as the previous day.

Upon **completion of the 7:00 p.m. Sunday testing session**, you will undergo a short debriefing period to explain the events that occurred during the study and to answer any questions pertaining to the study.

Risks of Participation

The main potential risk of the study will be a feeling of possible sleepiness throughout and after the two day testing period. You may experience sleepiness for 1-2 days following the partial sleep deprivation nights. Sleepiness may cause feelings of fatigue, decreased motivation, a change in performance, and a change in cognition that can last for one day following testing procedures. Academic performance or other activities such as judgment and response time driving may be effected for several days after sleep deprivation. This sleepiness can be minimized by getting adequate (about 8-10 h) amounts of sleep following the testing period. At this time, your body should adjust to it's normal sleep rhythm.

Additional risks can occur with sport skill testing such as strains, sprains, contusions, and abrasions. These risks are no different than those you experience at you rpractice and game sessions. Please try to wear appropriate footwear and athletic clothing to minimize these sport risks.

____
Initial Here

For More Information

Additional details pertaining to this study can be obtained by contacting:

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Withdrawal From The Study

Participation in this study is purely voluntary. You are free to withdraw from the study at any time you choose and your decision to do so will be respected. Please drop me a confidential note informing me of your withdrawal from the study so that you can receive your debriefing statement in a timely fashion.

Confidentiality

Questionnaire answers, test data, and performance data will all be kept confidential. This information will never be presented in such a way that a subject could be identified or associated with the study in any way. Data will be presented in group format. The last five digits of your social security number will be used as the identification method throughout the study and data analysis period only.

I have read the above and understand its contents fully and I agree to participate in this study. I acknowledge that I am 18 years of age or older (Please sign and date).

____

Signature

____

Date

APPENDIX C

Sleep Quality Scale

ID #______________________________

For the following statements, please circle the response that accurately reflects your quality of sleep. Thank you.

SLEEP QUALITY (GENERAL)

1.	I feel tired after getting up in the morning.	Agree / Disagree
2.	I usually sleep deeply during the night.	Agree / Disagree
3.	I often lie awake for more than half an an hour before falling asleep.	Agree / Disagree
4.	I often wake up several time during the night	Agree / Disagree
5.	I usually fall asleep easily.	Agree / Disagree
6.	I usually sleep quietly.	Agree / Disagree
7.	I think that I usually enjoy my sleep	Agree / Disagree
8.	I often don't sleep for more than 5 hours	Agree / Disagree
9.	I often get up during the night.	Agree / Disagree
10.	I take a sleep drug regularly.	Agree/ Disagree

SLEEP QUALITY (SPECIFIC)

1.	I felt energetic after getting up this morning.	Agree / Disagree
2.	I did not sleep more than 5 hours.	Agree/ Disagree
3.	Last night I lay awake for more than half an hour before I fell asleep	Agree / Disagree
4.	I enjoyed last night's sleep very much	Agree / Disagree
5.	I slept deeply last night.	Agree / Disagree
6.	I felt tired after getting up this morning.	Agree / Disagree
7.	I woke up several times last night.	Agree / Disagree
8.	I had difficulty in falling asleep again after waking up last night. (If you didn't wake up last night answer this question with disagree)	Agree / Disagree
9.	I felt rested after getting up this morning	Agree / Disagree
10.	I fell asleep easily last night.	Agree / Disagree
11.	I think I slept quietly last night.	Agree / Disagree

Do You Regularly Use Caffeine Products? Yes / No Amt. Per Day?______

APPENDIX D

Sleepiness Scale

ID #___________ TEST TIME: Baseline 9:00 AM

SLEEPINESS SCALE

AFTER READING THE FOLLOWING SEVEN STATEMENTS: PLEASE CIRCLE THE STATEMENT WHICH BEST DESCRIBES HOW YOU FEEL RIGHT NOW. CIRCLE ONLY ONE VALUE!!

---

1 – Feeling active and vital; alert; wide awake.

2 – Functioning at a high level, but not at peak; able to concentrate.

3 – Relaxed; awake; not at full alertness; responsive.

4 – A little foggy; not at peak; let down.

5 – Fogginess; beginning to lose interest in remaining awake; slowed down.

6 – Sleepiness; prefer to be lying down; fighting sleep; woozy.

7 – Almost in reverie; sleep onset soon; lost struggle to remain awake.

APPENDIX E

Five-hour history Form

ID Number____________________ Testing Session____________________________

IN THE FIVE HOURS PRIOR TO THIS SESSION, DID YOU:

(please circle)

Use any alcohol products	yes	no
Take any type of drug (including aspirin)	yes	no
Consume any type of caffeine product (i.e. coffee, soda, tea)	yes	no
Smoke a cigar, cigarette, pipe or use any chewing tobacco	yes	no
Partake in any sleep sessions, including a short nap	yes	no

LIST ITEMS EATEN SINCE LAST TESTING SESSION:

____

____

____

____

APPENDIX F

24 Hour History

Name:________________________ Date:________________________

HOW MUCH SLEEP DID YOU GET LAST NIGHT? (please circle one)

1 2 3 4 5 6 7 8 9 10 11 12 hours

HOW MUCH SLEEP DO YOU NORMALLY GET? (please circle one)

1 2 3 4 5 6 7 8 9 10 11 12 hours

HOW LONG HAS IT BEEN SINCE YOUR LAST MEAL OR SNACK? (please circle)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 hours

LIST ITEMS EATEN BELOW:

____

WHEN DID YOU LAST:

Have a cup of coffee, tea, or other caffeine product ________________________

Smoke a cigar, cigarette, pipe, or use chewing tobacco ______________________

Take drugs (including aspirin) ____

Drink alcohol ____

Give blood ____

Have an illness ____

Suffer from respiratory problems ____

WHAT SORT OF PHYSICAL EXERCISE DID YOU PERFORM YESTERDAY ?

WHAT SORT OF PHYSICAL EXERCISE DID YOU PERFORM TODAY?

DESCRIBE YOUR GENERAL FEELINGS BY CHECKING ONE OF THE FOLLOWING:

____________ Excellent	____________ Bad
____________ Very, Very Good	____________ Very Bad
____________ Very Good	____________ Very, Very Bad
____________ Neither Bad Nor Good	____________ Terrible

APPENDIX G

Debriefing Statement

The study in which you have participated examined the effects of partial sleep deprivation on sport-specific basketball skills and related cognitive processes needed in the game of basketball. In the past, there has been conflicting data involving the effects of partial sleep deprivation on physical performance. Partial sleep deprivation studies have in the past seen an increase in hand steadiness, a linear increase in sleepiness ratings, deterioration in reaction time, and a decrease in leg strength. We are trying to determine if 2 ½ hours of sleep is a sufficient amount of rest to still ensure optimal athletic performance.

We are also attempting to determine if your "morningness/eveningness" classification has an effect on the time of day that you perform these skills/tests under a partially sleep deprived condition. Conventionally, morning type people have been referred to as "larks" (early risers, early retires) and evening people have been referred to as "owls" (late risers, late retires). Personality scales have paired larks with introvert personalities and owls with extravert personalities. Larks are said to be better performers earlier in the day where as owls have been said to have better performance in the later hours of the day. As you probably realize, games and practices are held at different times of the day and thus performance can be affected depending on how strongly a person is classified as this sleep type.

If you would like further information regarding this study, contact the principal investigators at the addresses below.

Thank you, once again, for your participation in this study,

Sincerely,

Leigh A. Sears

Karen Lynn Uhl

Leigh A. Sears
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Marietta, OH 45750
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APPENDIX H

Description of Skill Tests

The basketball skill test is designed to measure performance of selected basketball skills. The test battery consists of four items: control dribble, passing, defensive movement, and speed shooting. Intraclass reliability coefficients ranged from R = .82 to .97 for all items. In addition, validity ratings for test items ranged from R =.65 to .95 (Hastad & Lacy, 1989).

The control dribble consist of dribbling through a set pattern of cones. At the start, the athlete begins dribbling with the nondominant hand from the nondominant side of starting cone A to the nondominant side of center cone B and proceeds through the course as depicted in Figure H- 1. Two officially timed trials are taken. The score for each trial will be the elapsed time required to correctly complete the course. Scores should be recorded to the nearest tenth of a second for each trial. The final score is the sum of the two trials.

The passing test consists of the athlete standing behind a restraining line, facing the wall, holding a basketball (Figure H - 2). On the start, the athlete executes a chest pass toward the first target, retrieves the ball while moving into position facing a second target, and executes a chest pass toward target B. This sequence is continued until the student reaches target F. At target F, the subject completes two passes toward the target and reverses the sequence back to target E, D, and so on. Two officially timed 30-second trials are allowed. Each pass hitting the target or the outline counts two points. A pass hitting wall space between the targets counts one point. The sum of points earned in each trial is recorded as the score.

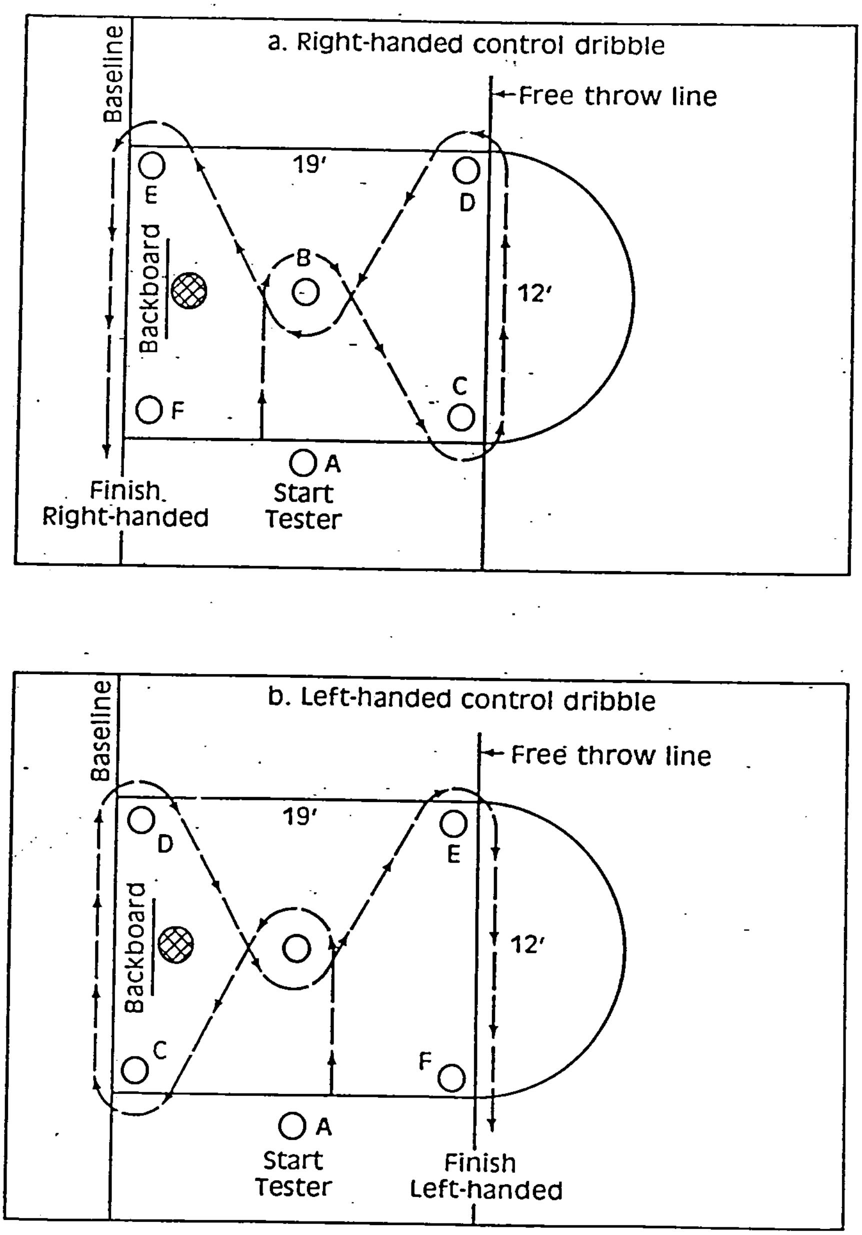

Figure H – 1. Layout for control dribble.

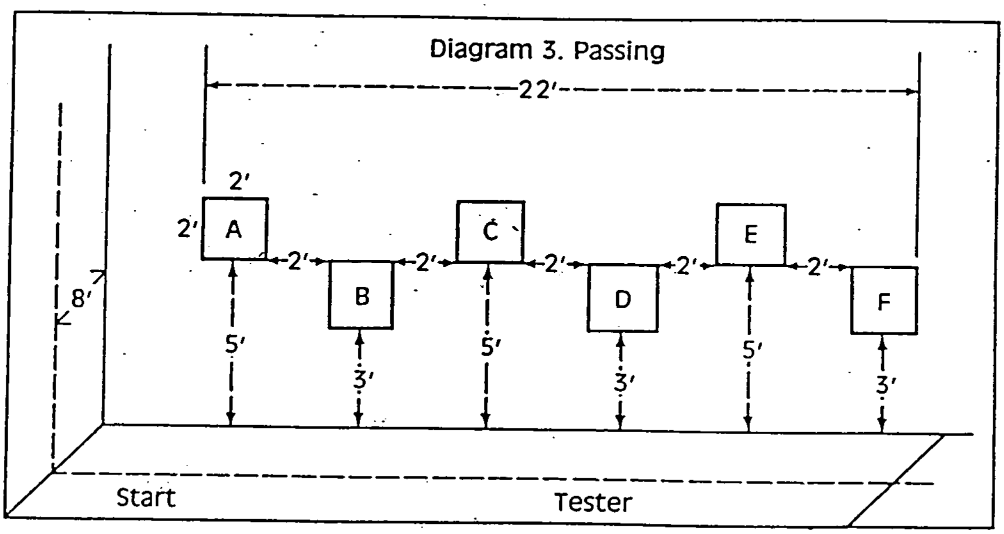

Figure H – 2. Layout for basketball wallpass.

For the speed shot shooting test the subject assumes a ready position behind any one of five shooting spots placed 15 feet away (Figure H - 3). At the start, the subject shoots at the basket, rebounds the ball, dribbles to another shooting spot, and shoots. The subject must attempt at least one shot from each of the five spots. A maximum of four lay-ups is allowed during a trial, but no two may be in succession. Two officially timed 60-second trials are allowed. Two points are awarded for each shot made. One point is awarded for each shot not made that hits the rim on its downward flight. The total points accumulated for both of the trials are recorded as the score.

Within the defensive movement test, the subject assumes a defensive position (legs flexed at the knees with feet spread) on point A, facing away from the basket (Figure H - 4). On the signal "Ready Go", the subject slides to the left to point B, touches the floor outside the free-throw lane with the left hand, performs a drop step and slides to point C and touches the floor outside the free throw lane with the right hand. The subject continues through the course as mapped out until both feet cross the finish line (diagonal return to point A). A practice trial is followed by two officially timed trials. The total time elapsed for both trials is counted as the score.

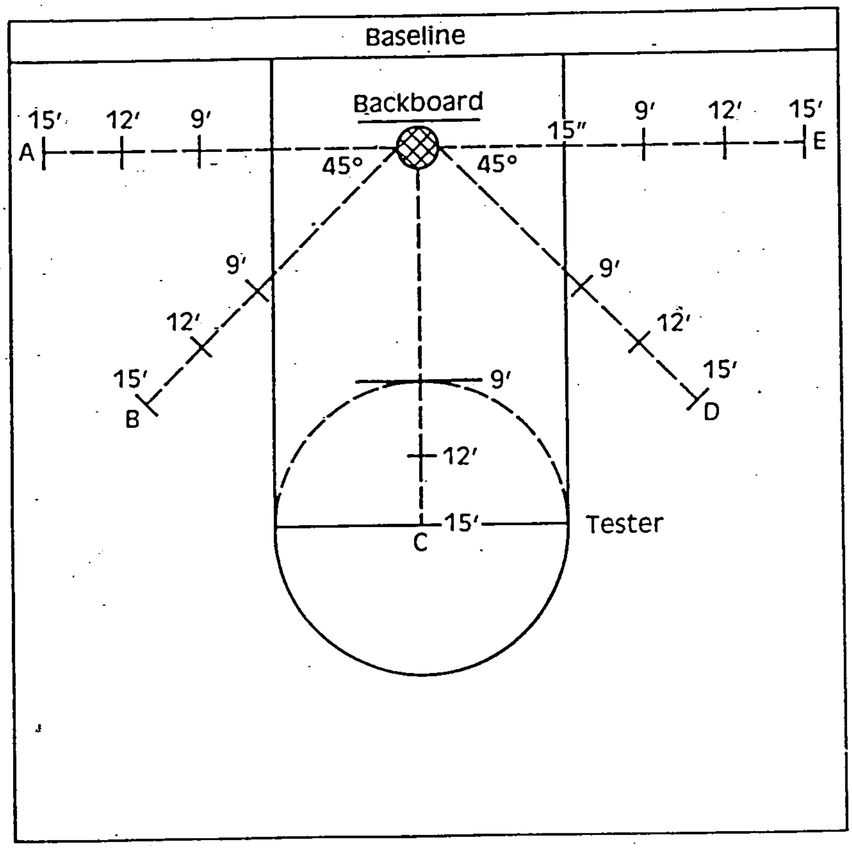

Figure H – 3. Layout for speed shot shooting.

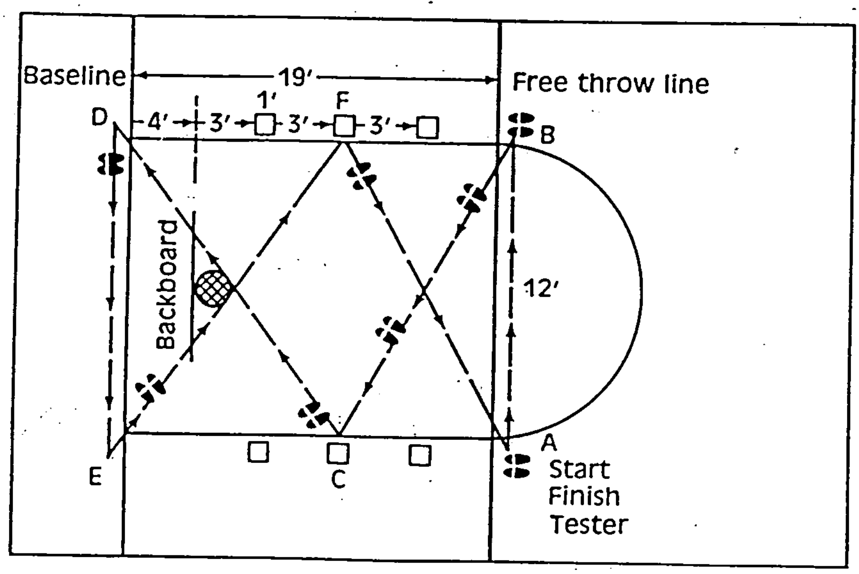

Figure H – 4. Layout for defensive movement.

REFERENCES

Hastad, D. N., & Lacy, A. C. (1989). Measurement and Evaluation in Contemporary Physical Education. Scottsdale: Gorsuch Scarisbrick Publishers, 306-312.

APPENDIX I

Raw Data

TABLE I-1

Raw Data for Vertical Jump

SUBJECT	base 9 a.m.	base 2 p.m.	base 7 p.m.	Psd1 9 a.m.	psd1 2 p.m.	psd1 7 p.m.
1	29.20	29.20	30.40	38.50	39.00	40.50
+ 2	35.50	38.00	33.00	38.00	36.80	38.00
3	22.50	23.00	26.50	24.00	23.50	27.00
+ 4	33.00	33.00	26.80	35.50	39.30	36.80
5	35.50	44.50	35.00	35.00	36.00	36.50
6	35.50	39.00	37.00	42.00	40.50	41.00
+ 7	26.60	29.20	30.40	27.90	29.20	26.60
8	43.00	38.00	43.00	39.30	43.00	41.90
+ 9	32.50	33.50	33.00	31.00	31.50	31.50
+10	34.50	35.50	36.00	33.50	33.50	33.00
+11	33.00	30.40	30.40	31.70	34.20	36.80
12	35.50	34.50	34.50	37.25	37.50	37.00
	psd2 9 a.m.	psd2 2 p.m.	psd2 7 p.m.			
1	38.50	39.50	39.00			
+ 2	34.20	33.00	33.00			
3	24.00	26.00	26.50			
+ 4	35.50	36.80	41.90			
5	35.50	34.00	36.00			
6	34.50	39.50	40.00			
+ 7	31.70	31.70	31.70			
8	41.90	43.00	41.90			
+ 9	32.00	30.50	30.50			
+10	33.00	34.50	35.00			
+11	30.40	35.50	36.80			
12	35.00	35.50	36.50			

Note.
Base = Baseline Testing; + six subjects BL tested before PSD; others BL tested after PSD

psd1 = Partial Sleep Deprivation Day 1

psd2 = Partial Sleep Deprivation Day 2

TABLE I-2

Raw Data for Shooting

SUBJECT	base 9 a.m.	base 2 p.m.	base 7 p.m.	psd1 9 a.m.	psd1 2 p.m.	psd1 7 p.m.
1	48.00	46.00	50.00	44.00	42.00	51.00
+ 2	50.00	44.00	45.00	53.00	44.00	43.00
3	47.00	38.00	42.00	41.00	40.00	44.00
+ 4	41.00	50.00	42.00	49.00	55.00	52.00
5	44.00	49.00	50.00	46.00	45.00	49.00
6	41.00	42.00	52.00	40.00	43.00	39.00
+ 7	42.00	44.00	43.00	43.00	46.00	42.00
8	47.00	49.00	51.00	45.00	44.00	43.00
+ 9	30.00	39.00	46.00	43.00	46.00	44.00
+10	44.00	44.00	41.00	52.00	43.00	47.00
+11	50.00	48.00	43.00	45.00	42.00	43.00
12	48.00	47.00	49.00	45.00	50.00	48.00
	psd2 9 a.m.	psd2 2 p.m.	psd2 7 p.m.			
1	45.00	52.00	47.00			
+ 2	45.00	46.00	46.00			
3	46.00	44.00	43.00			
+ 4	51.00	47.00	50.00			
5	48.00	42.00	48.00			
6	39.00	46.00	48.00			
+ 7	43.00	37.00	42.00			
8	37.00	48.00	47.00			
+ 9	48.00	49.00	36.00			
+10	50.00	51.00	51.00			
+11	39.00	40.00	45.00			
12	43.00	43.00	43.00			

Note.
base = Baseline Testing; + six subjects BL tested before PSD; others BL tested after PSD

psd1 = Partial Sleep Deprivation Day 1

psd2 = Partial Sleep Deprivation Day 2

TABLE I-3

Raw Data for Passing

SUBJECT	base 9 a.m.	base 2 p.m.	base 7 p.m.	psd1 9 a.m.	psd1 2 p.m.	psd1 7 p.m.
1	46.50	43.00	48.00	45.50	43.00	44.00
+ 2	44.00	45.50	46.00	48.00	47.00	43.00
3	41.00	42.00	42.00	40.00	42.00	42.00
+ 4	43.00	43.00	45.00	43.00	46.00	44.50
5	53.50	56.50	52.50	45.00	46.00	47.00
6	45.00	46.00	48.00	43.00	45.00	48.00
+ 7	44.00	41.50	42.00	40.00	40.00	42.50
8	45.50	45.00	47.00	37.00	43.00	43.00
+ 9	46.00	49.00	49.00	48.00	2.00	50.00
+10	47.50	47.00	49.00	47.50	51.00	50.00
+11	38.00	39.00	40.00	37.50	38.00	40.00
12	44.00	49.00	47.50	42.00	47.00	45.00
	psd2 9 a.m.	psd2 2 p.m.	psd2 7 p.m.			
1	44.00	46.00	43.00			
+ 2	40.50	47.00	45.13			
3	41.00	42.00	42.00			
+ 4	36.50	43.50	46.00			
5	48.00	47.50	51.00			
6	44.00	45.00	45.00			
+ 7	41.00	43.00	44.00			
8	41.00	46.00	46.00			
+ 9	51.00	50.50	52.00			
+10	50.50	51.50	51.00			
+11	38.00	39.50	40.50			
12	40.00	45.00	43.00			

Note.
base = Baseline Testing; + six subjects BL tested before PSD; others BL tested after PSD

psd1 = Partial Sleep Deprivation Day 1

psd2 = Partial Sleep Deprivation Day 2

TABLE I-4

Raw Data for Defensive Movement

SUBJECT	base 9 a.m.	base 2 p.m.	Base 7 p.m.	psd1 9 a.m.	psd1 2 p.m.	psd1 7 p.m.
1	13.16	13.26	12.56	13.40	13.52	13.15
+ 2	11.72	11.19	11.36	11.49	10.98	10.73
3	14.16	13.85	14.01	14.87	14.65	13.74
+ 4	8.99	12.51	11.61	11.72	11.75	11.69
5	11.82	11.20	11.23	13.16	11.98	11.73
6	11.25	11.56	11.50	12.09	11.64	10.92
+ 7	12.96	12.11	13.01	13.15	13.20	12.38
8	12.55	13.40	13.00	14.13	13.54	12.95
+ 9	14.05	13.02	12.58	13.10	12.45	12.70
+10	12.61	11.73	11.40	11.50	11.09	10.64
+11	14.11	14.05	14.07	15.72	14.82	14.38
12	12.67	11.87	12.05	12.46	12.71	12.64
	psd2 9 a.m.	psd2 2 p.m.	Psd2 7 p.m.			
1	13.48	13.26	13.30			
+ 2	13.10	11.51	11.51			
3	15.61	14.57	15.18			
+ 4	12.04	11.94	11.30			
5	11.76	11.62	11.39			
6	12.50	11.98	12.05			
+ 7	13.75	13.80	13.25			
8	13.63	13.24	12.82			
+ 9	12.20	12.32	12.70			
+10	10.94	10.46	10.78			
+11	15.47	14.05	14.06			
12	14.26	12.85	12.29			

Note.
Base = Baseline Testing; + six subjects BL tested before PSD; others BL tested after PSD

psd1 = Partial Sleep Deprivation Day 1

psd2 = Partial Sleep Deprivation Day 2

TABLE I-5

Raw Data for Dribbling

SUBJECT	base 9 a.m.	base 2 p.m.	base 7 p.m.	psd1 9 a.m.	psd1 2 p.m.	psd1 7 p.m.
1	15.40	15.30	15.90	15.60	15.60	16.50
+ 2	16.30	15.70	17.30	16.60	15.70	15.80
3	16.80	17.30	16.40	19.30	19.50	19.20
+ 4	15.90	15.20	15.20	14.10	14.40	14.80
5	13.70	14.00	13.80	16.60	16.20	15.90
6	15.10	14.90	14.80	17.00	17.20	16.70
+ 7	16.10	16.60	16.20	18.80	17.80	17.10
8	16.30	15.90	15.40	17.40	18.10	16.20
+ 9	15.30	15.40	14.90	15.00	14.50	14.80
+10	15.70	15.20	14.30	16.00	14.30	14.00
+11	19.00	19.90	20.30	20.30	21.70	21.50
12	14.90	15.00	15.80	17.50	16.80	16.60
	psd2 9 a.m.	psd2 2 p.m.	psd2 7 p.m.			
1	16.10	15.30	15.80			
+ 2	16.40	16.30	16.30			
3	19.10	17.20	18.00			
+ 4	13.40	15.10	14.60			
5	15.30	14.60	14.50			
6	17.20	16.10	16.20			
+ 7	18.90	19.20	18.20			
8	17.60	17.80	17.10			
+ 9	14.20	14.20	14.70			
+10	14.00	13.80	14.20			
+11	19.80	21.80	18.00			
12	17.50	16.10	16.30			

Note.
base = Baseline Testing; + six subjects BL tested before PSD; others BL tested after PSD

psd1 = Partial Sleep Deprivation Day 1

psd2 = Partial Sleep Deprivation Day 2

APPENDIX J

Data Tables

Table J – 1

Descriptive Statistics for Vertical Jump

Day	Time	M	SD
BL	9 a.m.	83.89	13.10
	2 p.m.	86.30	14.35
	7 p.m.	85.92	10.82
PSD-1	9 a.m.	87.55	13.08
	2 p.m.	89.73	13.66
	7 p.m.	90.29	12.87
PSD-2	9 a.m.	85.97	11.12
	2 p.m.	88.79	11.50
	7 p.m.	90.75	11.96

Note. Units are in centimeters,

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partial Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J – 2

Analysis of Variance for Vertical Jump

Source	df	SS	MS	F	P
day within subjects	2	46.28	23.14	1.70	0.205
within + residual	22	299.16	13.60		
time within subjects	2	31.34	15.67	6.21	0.007
within + residual	22	55.54	2.52		
day x time	4	4.36	1.09	0.31	0.873
within + residual	44	156.92	3.57		

Tukey HSD Post-Hoc for Vertical Jump Time Main Effect

Significant differences between:

9 a.m. (85.80) ≠ 2 p.m. (88.29)

9 a.m. (85.80) ≠ 7 p.m. (89.00)

Table J - 3

Descriptive Statistics for Free Throws

Day	Time	M	SD
BL	9 a.m.	6.50	1.24
	2 p.m.	6.83	1.40
	7 p.m.	7.33	1.30
PSD-1	9 a.m.	5.92	1.83
	2 p.m.	6.67	1.83
	7 p.m.	7.00	1.21
PSD-2	9 a.m.	6.58	1.73
	2 p.m.	7.50	1.38
	7 p.m.	7.17	1.59

Note. Units are in number of shots made out of 10,

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partail Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J - 4

Analysis of Variance for Free Throws

Source	df	SS	MS	F	P
day within subjects	2	5.72	2.86	1.5	0.244
within + residual	22	41.83	1.9		
time within subjects	2	14.00	7.00	4.10	0.031
within + residual	22	37.56	1.71		
day x time	4	2.78	0.69	0.3	0.873
within + residual	44	100.33	2.28		

Tukey HSD Post-Hoc for Free Throws Time Main Effect

Significant differences between:	9 a.m. (6.33) ≠ 7 p.m. (7.17)

Table J - 5

Descriptive Statistics for Passing

Day	Time	M	SD
BL	9 a.m.	44.75	3.70
	2 p.m.	45.54	4.58
	7 p.m.	46.33	3.56
PSD-1	9 a.m.	43.04	3.88
	2 p.m.	45.00	4.11
	7 p.m.	44.92	3.20
PSD-2	9 a.m.	42.96	4.69
	2 p.m.	45.54	3.39
	7 p.m.	45.72	3.75

Note. Units are number of targets hit

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partial Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J – 6

Analysis of Variance for Passing

Source	df	SS	MS	F	P
day within subjects	2	29.13	14.57	1.61	0.222
within + residual	22	198.52	9.02		
time within subjects	2	87.99	43.99	14.31	0.000
within + residual	22	67.63	3.07		
day x time	4	12.26	3.06	1.18	0.331
within + residual	44	113.85	2.59		

Tukey HSD Post-Hoc for Passing Time Main Effect

Significant differences between:	9 a.m. (43.61) ≠ 2 p.m. (45.36)
	9 AM (43.61) ≠ 7 PM (45.66)

Table J –7

Descriptive Statistics for Defensive Movement

Day	Time	M	SD
BL	9 a.m.	12.50	1.46
	2 p.m.	12.48	1.01
	7 p.m.	12.37	1.01
PSD-1	9 a.m.	13.07	1.34
	2 p.m.	12.69	1.28
	7 p.m.	12.30	1.19
PSD-2	9 a.m.	13.23	1.44
	2 p.m.	12.63	1.20
	7 p.m.	12.55	1.27

Note. Units are in seconds,

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partial Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J – 8

Analysis of Variance for Defensive Movement

Source	df	SS	MS	F	P
day within subjects	2	2.36	1.18	2.16	0.140
within + residual	22	12.04	0.55		
time within subjects	2	5.08	2.54	10.22	0.001
within + residual	22	5.47	0.25		
day x time	4	1.80	0.45	1.82	0.141
within + residual	44	10.86	0.25		

Tukey HSD Post-Hoc for Defensive Movement Time Main Effect

Significant differences between:

9 a.m. (12.93) ≠ 2 p.m. (12.60)

9 a.m. (12.93) ≠ 7 p.m. (12.41)

Table J - 9

Descriptive Statistics for Dribbling

Day	Time	M	SD
BL	9 a.m.	15.88	1.28
	2 p.m.	15.87	1.52
	7 p.m.	15.86	1.69
PSD-1	9 a.m.	17.02	1.80
	2 p.m.	16.82	2.22
	7 p.m.	16.59	2.04
PSD-2	9 a.m.	16.62	2.10
	2 p.m.	16.46	2.29
	7 p.m.	16.16	1.45

Note. Units are in seconds,

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partial Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J – 10

Analysis of Variance for Dribbling

Source	df	SS	MS	F	P
day within subjects	2	16.10	8.05	4.77	0.019
within + residual	22	37.13	1.69		
time within subjects	2	1.67	0.83	1.79	0.190
within + residual	22	10.23	0.46		
day x time	4	0.76	0.19	0.52	0.719
within + residual	44	16.00	0.36		

Tukey HSD Post-Hoc for Dribbling Main Day Effect

Significant differences between: BL (15.87) ≠ PSD-1 (16.81)

Table J – 11

Descriptive Statistics for Shooting

Day	Time	M	SD
BL	9 a.m.	44.33	5.55
	2 p.m.	45.00	3.91
	7 p.m.	46.17	4.02
PSD-1	9 a.m.	45.50	4.01
	2 p.m.	45.00	4.05
	7 p.m.	45.42	3.94
PSD-2	9 a.m.	44.50	4.48
	2 p.m.	45.42	4.44
	7 p.m.	45.50	4.08

Note. Units are in number of shots made in one minute,

Days include: Baseline (BL),

Partial Sleep Deprivation Day 1 (PSD-1),

Partial Sleep Deprivation Day 2 (PSD-2).

N = 12

Table J - 12

Analysis of Variance for Shooting

Source	df	SS	MS	F	P
day within subjects	2	0.57	0.29	0.01	0.987
within + residual	22	473.20	21.51		
time within subjects	2	15.35	7.68	0.65	0.531
within + residual	22	259.09	11.78		
day x time	4	14.43	3.61	0.24	0.911
within + residual	44	648.46	4.74		