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Does Sleep Affect Delayed Onset Muscle Soreness (DOMS) In Olympic Hockey Players?

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DOES SLEEP AFFECT DELAYED ONSET MUSCLE SORENESS (DOMS) IN OLYMPIC HOCKEY PLAYERS?

by

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This thesis, submitted by Monique Lamoureux in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

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Dean of the School of Graduate Studies

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To Mom and Dad

Abstract

A quantitative study was conducted on the 2014 USA Women's Olympic Hockey Team. Data was collected from the participants asking for the hours of sleep they got the previous night and how sore they were from the training on the previous day. These numbers were then analyzed to see if athletes who got less sleep reported higher soreness ratings. Results showed that two days in Training Cycle 1 had two significant *p*-values that coincided with the two strongest negative correlations. Training Cycle 3 had one significant *p*-value trending in the opposite direction of the proposed hypothesis. The hours of sleep reported by the participants may show that sleep needs were not being met in order to achieve maximal recovery from the previous day of training. Further research is suggested to support the hypothesis and to determine the type of relationship that exists between sleep and DOMS.

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Sleep is vital for every human being. According to the National Sleep Foundation (NSF), from puberty to age twenty-six, the average person requires between 7 and 9 hours of sleep. Statistics published by the Center for Disease Control (CDC, 2008) show that over the past fifty years the duration of sleep for adolescents and adults has decreased 1.5-2 hours a night and that more than 30% of Americans report getting less than six hours of sleep per night. In addition, an overwhelmingly large percentage of individuals in the United States have chronic sleep loss (Dement, 2005).

Athletes undoubtedly need more sleep than sedentary people given their need for sufficient recovery from muscle soreness and damage that comes from intense training and competition. When athletes are training, skeletal muscle is damaged, called Exercise Induced Muscular Damage (EIMD). One of the most common ways for EIMD to occur is through eccentric contractions and usually results in Delayed Onset Muscle Soreness (DOMS). DOMS occur from small microtraumas to the skeletal muscle from movement and its onset occurs 24-48 hours after exercise (Howatson & Someren, 2008). Due to the similarities in DOMS and EIMD, they are typically used interchangeably because the damage caused from EIMD results in DOMS. The greater the damage (EIMD), the greater the onset of DOMS will be. Unfamiliar, new, prolonged, or unaccustomed exercises that include eccentric movements can cause increased muscle soreness, increased swelling, and increased intramuscular protein in the blood (Howatson & Someren, 2008). This occurs during eccentric exercise because fewer motor units are recruited resulting in a smaller cross-sectional area that is activated to handle the same load compared to the concentric contraction (Clarkson & Sayers, 1999; Enoka, 1996). Depending on the intensity and load of the exercise, muscle stiffness and soreness is experienced from 1-4 days post-exercise (Howell, Chleboun, & Conaster, 1993). Multiple mechanisms contribute to muscular damage following eccentric exercises, but further research is needed to evaluate mechanisms that are involved in the damage/repair process following EIMD (Clarkson & Sayers, 1999).

Muscular repair is essential for athletes in training because they are consistently putting stress on the body and musculoskeletal system, and if insufficient repair occurs, the resulting performance benefits can plateau or decline (Chiong, 2009). Sleep loss and fatigue affect the recovery process. Common strategies to address recovery have not, however, included sleep. In their review, Howatson and Someren (2008) found that the most common strategies for prevention and treatment of EIMD (and DOMS) were nutritional and pharmacological strategies, electrical and manual therapies, and exercise. The benefits of sleep are tied to Human Growth Hormone (HGH) stimulating protein synthesis, a process that peaks during sleep. Consequently, sleep could be considered as a recovery/prevention strategy for muscle soreness (Plowman & Smith, 1997).

The amount of sleep an individual gets influences their endocrine response. Researchers have shown that when participants are restricted in the amount of sleep they get, there is an increase in the “stress hormone,” cortisol, because the body isn’t able to down regulate it’s release (Spiegel, Leproult, & Can Cauter, 1999). There is also decreased release of HGH, which plays a significant role in muscular recovery (Spiegel et al., 1999). Seventy percent of HGH release happens during the first half of an individual’s nightly sleep (see also Redwine, Hauger, Gillin, & Irwin, 2000), but if an individual is sleep deprived or has partial sleep loss, the release is significantly hampered, and in severe cases, abolished (Mullington et al., 2008). HGH can be described as a sleep-dependent hormone. The combination of restricted HGH release and higher levels of cortisol does not allow the body to maximize the process of protein synthesis, and is associated with a higher fat mass which would likely decrease an athlete’s performance (Banks & Dinges, 2007).

Sleep is divided into two different categories: REM (rapid eye movement) and non-REM sleep, as described by Chiong (2006). Non-REM sleep is divided into four different stages that are distinguished by brainwaves and function. One enters Stage I of non-REM sleep when they drift off to sleep, while brainwaves become regular and slower which make the muscles relax. Theta waves govern brain activity during Stage 1 of sleep. The true beginning of sleep starts in Stage 2 of non-REM where the individual has complete disengagement from their surroundings. Theta waves also dominate this stage, but the main difference compared to Stage 1 is that sleep spindles appear in Stage 2. Stages 3 and 4 are the deepest stages of sleep throughout the night and delta waves dominate brain activity in both of these stages. Slow Wave Sleep (SWS) is part of stages 3 and 4 of non-REM sleep. During these two stages of sleep, blood pressure and heart rate decrease, and the secretion of HGH peaks while the release of cortisol is inhibited

(Cauter et al., 2008). These last two stages are considered to be vital to athletes because the HGH stimulates protein synthesis, implying that the longer time spent in these stages influences recovery after muscular damage inflicted from training or practice (Chiong, 2009), and that sleep loss impairs protein synthesis and leads to incomplete muscular restoration (Datillo et al., 2011). Sleep disturbances have also been found to decrease time spent in stages 3 and 4 of sleep and can diminish the release of HGH. The main difference between stages 3 and 4 of sleep is that delta waves are more prominent in stage 4 compared to stage 3, meaning while in stage 4, an individual is in a deeper sleep (Chiong, 2009). Less than an hour into sleep, one returns to stages 3 and 2, and then the sympathetic nervous system kicks in and blood flow to the brain, heart rate, blood pressure, respiration, and body temperature all increase and one enters REM sleep.

REM sleep is important because it is where memory and motor learning is solidified from the day's prior experiences. It takes the average person 90 minutes to go through one sleep cycle (Chiong, 2006). Figure 1 shows a normal 8-hour sleep-cycle of an adult. When an individual gets an adequate amount of sleep, they will enter REM sleep four or five times throughout the night, and each time one enters REM, 40-50% more time is spent in REM compared to the previous cycle (Chiong, 2006). Stage 2 of the sleep cycle becomes crucial after about 6.5 hours of sleep because the appearance of sleep spindles occur, causing the release of calcium into the motor cortex, allowing an individual to have better subconscious recall of motor patterns (Chiong, 2009; Maas & Robbins, 2011).

SWS may aid in recovery (Shapiro et al., 1981). For example, in an experiment looking at six participants who performed an extreme physically taxing event (92km road race) and the amount of time they spent in different stages of sleep, Shapiro et al. (1981) showed that the participants spent significantly more time sleeping, and in particular, more time in stages 3 and 4 during the four days after the event. During the

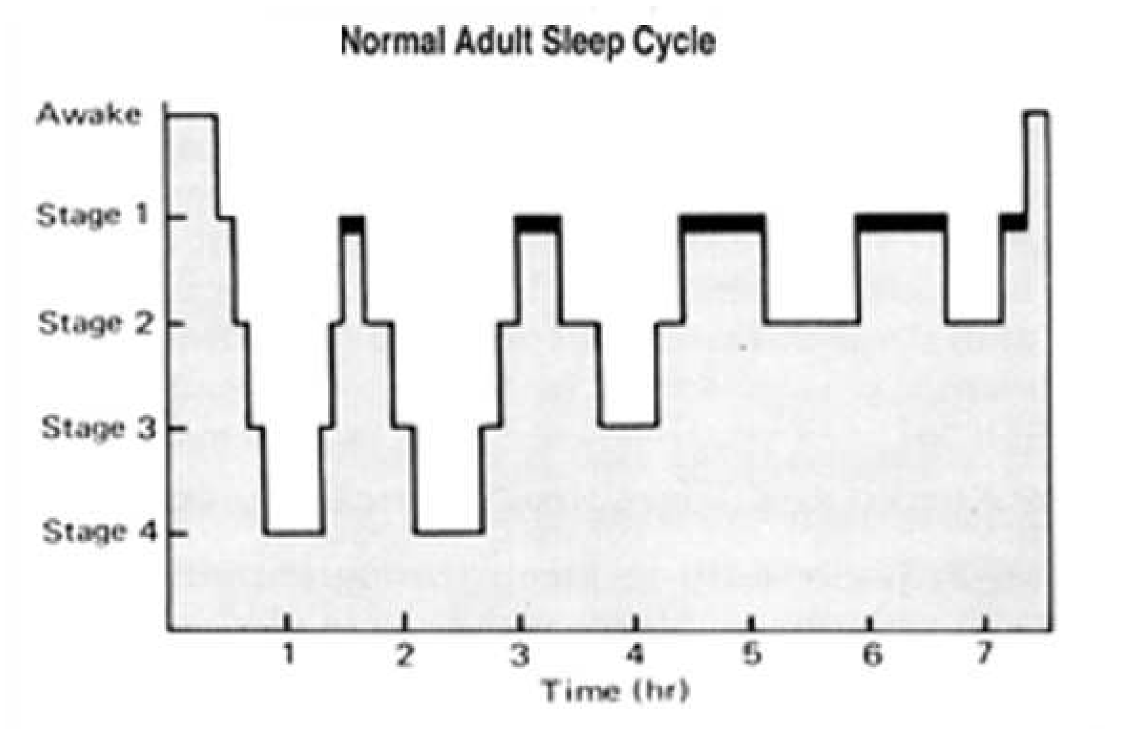

Figure 1 Graph of a normal 8-hour sleep cycle.

first two nights after the race, participants spent over 20% more time than normal in SWS, indicating that SWS increases after extreme metabolic demands. The researchers concluded that SWS acts as a recovery period. Thus, sleep seems to be a relatively simple recovery method that athletes can use when muscular damage occurs.

Most researchers who have examined sleep relative to athlete performance have investigated sleep deprivation. Their research has shown that partial sleep deprivation can affect performance. For example, in one experiment (Reily & Piercy, 1994), participants were restricted to three hours of sleep for successive nights followed by the participants performing maximal and submaximal exercises for dead lift, bicep curl, bench press, and leg press. Results indicated that there was a decreased performance in all four submaximal lifts, and three of the four maximal lifts (bench press, leg press, dead lift). In another experiment, researchers looked at the effects of sleep deprivation on cognitive and motor performance and mood by examining participants after 30 hours of sleep deprivation with intermittent physical exercise or sedentary wakefulness (Scott, McNaughton, & Polman, 2005). The sedentary and exercise groups both had increases in reaction times, but the exercise group saw greater increases in reaction times than the sedentary group. It is a common belief that exercise can help an individual become more alert when inadequate sleep is present, but it does not appear to activate the body enough in order to prevent decreases in performance when participants are sleep deprived. These results show that decreased sleep affects training and performance.

Researchers have shown that lack of sleep can affect athletes' cognitive and physical performance (Reily & Piercy, 1994; Scott et al., 2005) and that sleep aids in muscular repair (Maas & Davis, 2013). If lack of sleep affects an athlete's ability to repair the muscular damage that has occurred, then it can be implied that the athlete will report a higher pain rating and prolonged time period experiencing symptoms of muscle soreness. In a research study (i.e., Skein et al., 2013) conducted with rugby players the night after a competitive game, results showed that the sleep deprived group reported being more physically fatigued, had slower cognitive function, decreased lower-body power output, and a greater rating of muscle soreness. In another study, Lentz, Landis, Rothemel, and Shaver (1999) disrupted the SWS of sedentary middle-aged women for three consecutive nights and found a 24% decrease in musculoskeletal pain threshold.

Other researchers have examined the relationship between soreness and force production. Results from muscle biopsies have shown when individuals do resistance exercises, specifically the concentric phase or eccentric phase of an arm curl, myofibrillar disruption occurs immediately post exercise and 48 hours post exercise, but there was 40% more disruption on the eccentric phase of the arm curl (Gibala et. al, 1995). In another study, Howell, Chleboun, and Conatser (1992) discovered that after three bouts of an eccentrically loaded arm curl, muscle soreness lasted for up to seven days but peaked on the second day post exercise, and muscle strength dramatically declined 35% the day after exercise and only returned to about 70% of control strength after the tenth day, and stiffness steadily increased until the third day post exercise and returned to normal by day six. Similar findings were also found when Prasarhwuth, Taylor, and Gandevia (2005), measured maximal force, voluntary activation, and muscle soreness after eccentric damage occurred to the elbow flexor muscles. These above studies do not address if sleep can affect soreness or reduce the effect of force production decreasing after resistance exercises.

Olympic and national team athletes make many sacrifices in order to become the best at what they do. Adjustments are made to nutrition and training depending on the time of the year and goals of the athlete in order to perform at their best. Obtaining an adequate amount of sleep may be a neglected performance enhancer for athletes, but to our knowledge, little to no research has been done on how sleep can affect an individual's soreness (DOMS) throughout a training cycle. This gap in research allows the author to look at sleep and soreness in an athlete's typical training environment over an extended period of time. If an athlete is less sore, they will be able to push themselves more, resulting in lifting more weights, running faster, or whatever the activity may be, thus making greater improvement while training. It is hypothesized that athletes who get more sleep will experience less delayed onset muscle soreness (DOMS) throughout a training cycle.

CHAPTER II

METHOD

Participants

Each participant (N=24) was a member of the 2013-2014 USA Women's National Hockey Team. Twenty-one of the 25 participants became a member of the 2014 USA Women's Olympic Team. The age range of participants was 16 to 32 years (Mean = 23 years).

Measures

Sleep

There are different devices/methods to measure sleep, but it appears that there is not one measure that is significantly preferred over the other and that discrepancies often appear when comparing data (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2009; Tryon, 2004). Although sleep labs are the most accurate way to measure sleep, due to the environment, setting, and cost, utilizing a sleep lab was not practical. For this study, sleep was measured by self-report. Participants were asked to record the number of hours they slept the previous night. A limitation of this method is that when sleep is self-reported, participants on average report obtaining 45 minutes to one hour more sleep than the actually got (Lauderdale et al., 2009).

DOMS

There is no one method that stands above the rest when measuring DOMS because it is a subjective measure. Techniques, such as muscle biopsies can measure the damage done to muscles after training, but are invasive, painful, and costly (Hani, Jerrold, Michael, & Lee, 2012). With that being said, DOMS was self-reported using the most widely used tool for measuring DOMS, the Visual Analogue Scale (VAS). The VAS is a visually horizontal line that participants can look at and gauge the characteristic or attitude being evaluated (Crichton, 2001). Some VAS versions use a horizontal line with visual ticks of a scale from 0-10 (Wewers & Lowe 1990). Strengths and weaknesses have been reported using VAS (Wewers & Lowe, 1990), but it was the most efficient and cost effective way to measure DOMS in this particular setting. In this study, participants were asked to rate their soreness on a scale of 0-10, where 0 = "*very little to no soreness*" and 10 = "*painfully sore to the point of injury*," and record it into the computer. If a participant recorded a 0, then they had no muscular soreness.

Procedure

The data used in this study was collected as a part of the training by the USA Women's Hockey Team prior to the 2014 Winter Olympics. At the beginning of the training season when all of the players started their season together, the team was informed by the strength and conditioning coach that data was being collected to monitor the athlete's sleep and soreness. Weight lifting/dryland were scheduled two or three days a week depending on the game schedule. Each athlete was asked to fill out a "*Readiness Questionnaire*" each day that data was being collected. The questionnaire included the questions about sleep and DOMS. The data were collected on a computer that each athlete filled in voluntarily before the start of warming up. It took approximately 10-30 seconds for each athlete to fill out the questionnaire each day. Because this data was pre-existing, IRB approval was obtained (Appendix A). Permission from USA Hockey was granted in order to use the data (Appendix B).

Data were collected using Microsoft Excel over a six-month period. Forty-four days of data were collected, 28 of which are included in the data analysis. Data from the months of September, October, November, and December were included in this study because those months contained the most number of days of recorded data.

The data were collected from five different mesocycles which were each four weeks long. The intensity of the workouts increased each week with an unloading week on the fourth week in order to achieve maximal benefits from the training (See Appendix C for workout information). Mesocycles one, two, three, and five were cycles in which strength was either maintained or improved. During some of the cycles, the data collection was sporadic due to less frequent training because of travel, game schedule, and holiday break. Appendix D shows the dates of each day data was collected with the dates in bold to show the dates used in this study. Training cycles one and three were used because they had the most data. The calendar schedule is in Appendix E.

Data Analysis

Descriptive statistics were computed for Sleep and DOMS for all days and weekly totals. These values included average hours of sleep each night, range of sleep each night between all participants, average soreness rating, and range of soreness ratings between all participants. These values are displayed in Table 1. The relationship between sleep and DOMS were examined using Pearson Product-Moment correlations along with *P* values to examine the significance of the relationship between sleep and DOMS and are displayed in Table 2.

Table 1. Descriptive Statistics for Sleep and DOMS scores.

	Training Cycle 1						**Training Cycle 3**				
Week 1	**S10**	**S11**	**S13**	**S14**	**S15**	**Week**	**N12**	**N13**	**N14**		**Week**
Sleep M	7.76	7.41	7.80	7.67	7.44	7.62	8.09	8.88	8.14		8.37
SD	0.60	0.95	0.74	0.66	0.75	0.74	1.11	0.86	0.92		0.96
Range	7.0-9.0	5.3-9.0	6.5-9.0	6.5-9.0	6.0-9.0		7.0-10.0	7.5-10.0	6.0-10.0		
DOMS M	5.33	6.84	5.92	4.71	3.74	5.31	1.11	3.93	4.13		3.06
SD	1.63	1.64	1.73	1.78	1.61	1.68	1.11	1.39	1.56		1.35
Range	3.0-9.0	3.0-9.0	3.0-9.0	1.0-7.0	1.0-6.0		0.0-4.0	1-6.6.0	2.0-7.0		
Week 2	**S17**	**S18**	**S19**	**S20**	**S21**		**N18**	**N19**	**N20**	**N24**	
Sleep M	8.35	8.10	7.95	7.72	7.30	7.88	8.14	8.02	7.77	8.26	8.05
SD	0.76	0.58	0.77	0.81	0.89	0.76	0.81	0.94	1.22	1.43	1.10
Range	7.5-10	7.5-9.5	6.0-9.0	7.0-9.0	6.0-10.0		6.0-9.5	6.0-9.5	6.0-10.0	7.0-13.5	
DOMS M	2.07	3.30	2.83	2.10	2.12	2.48	2.24	3.60	3.38	4.05	3.32
SD	1.30	1.65	1.66	1.34	1.47	1.48	1.39	1.32	1.89	1.80	1.60
Range	0.0-4.0	0.0-6.0	0.0-5.5	0.0-6.0	0.0-5.0		0.0-6.0	1.0-6.0	0.0-7.0	0.0-8.0	
Week 3	**S23**	**S25**	**S28**				**D2**	**D3**	**D4**	**D5**	
Sleep M	8.08	7.78	6.93			7.60	8.25	7.96	7.59	6.47	7.57
SD	0.77	0.56	1.00			0.78	1.33	0.80	0.93	0.97	1.01
Range	7.0-10.0	6.5-9.0	5.5-8.5				7.0-11.0	7.0-10.0	6.0-10.0	6.0-9.0	
DOMS M	1.80	1.78	2.33			1.97	1.30	3.28	4.27	3.13	3.00
SD	1.32	1.93	1.77			1.67	1.11	1.62	1.72	1.20	1.41
Range	0.0-5.0	0.0-8.0	0.0-6.0				0.0-4.0	1.0-8.0	0.0-7.0	3.0-6.0	
Week 4	**S30**	**O2**	**O3**				**D9**	**D10**	**D14**		
Sleep M	7.57	7.80	8.17			7.85	7.63	7.60	8.36		7.86
SD	0.99	1.06	0.92			0.99	1.02	0.99	1.05		1.02
Range	5.5-10.0	5.0-10.0	6.75-10.0				7.0-9.5	5.0-9.0	6.5-11.0		
DOMS M	1.32	2.47	2.08			1.96	2.46	4.23	2.98		3.22
SD	1.72	2.09	1.67			1.83	1.42	1.45	1.42		1.43
Range	0.0-7.0	0.0-9.0	0.0-5.0				0.0-6.0	1.0-6.0	1.0-6.0		

Note: Sleep is self-reported at hours per night. DOMS measured on 1-10 scale where higher numbers indicate more soreness.

Table 2. Correlation and p values for Sleep and DOMS.

	Training Cycle 1						**Training Cycle 3**				
Week 1	**S10**	**S11**	**S13**	**S14**	**S15**	**Week**	**N12**	**N13**	**N14**		**Week**
r	0.15	-0.02	-0.14	0.24	-0.16	0.01	0.03	0.32	0.06		0.14
p	0.49	0.94	0.52	0.25	0.45		0.88	0.16	0.78		
Week 2	**S17**	**S18**	**S19**	**S20**	**S21**		**N18**	**N19**	**N20**	**N24**	
r	-0.11	0.25	0.20	-0.45	-0.36	-0.09	0.01	0.31	0.34	0.09	0.19
p	0.61	0.24	0.34	0.03	0.08		0.98	0.17	0.10	0.68	
Week 3	**S23**	**S25**	**S28**				**D2**	**D3**	**D4**	**D5**	
r	-0.44	-0.36	-0.38			-0.39	0.34	0.09	-0.26	0.84	0.25
p	0.03	0.07	0.07				0.13	0.69	0.24	0.00	
Week 4	**S30**	**O2**	**O3**				**D9**	**D10**	**D14**		
r	-0.22	-0.01	-0.27			-0.17	0.01	0.11	0.06		0.06
p	0.37	0.98	0.26				0.96	0.70	0.78		

Note: Sleep is self-reported at hours per night. DOMS measured on 1-10 scale where higher numbers indicate more soreness.

The minimum and maximum values for sleep were 5 to 13.5 hours. On average, athletes reported getting at least 7 hours of sleep per night (weekly averages ranged from 7.57 to 8.37 hours). There were no differences in weekly averages within or between training cycles, showing that athletes did not sleep any more (or less) during specific weeks of the training cycles.

The minimum and maximum values for DOMS were 0 to 9. On average, athletes reported a soreness rating of 3.04 (weekly averages ranged from 1.96 to 5.31). Aside from week 1 of Training Cycle 1 (TC1), weekly averages of DOMS were within a .5 rating within and between training cycles. Week 1 of TCI had an average DOMS rating of 5.31, significantly higher than other weekly averages. As a whole, it took participants over five days to return to the average soreness rating.

Correlations were computed for daily and weekly values. There was a difference in correlations when computing TC1 and Training Cycle 3 (TC3). Of the 16 recorded days in TC1, 12 of the days had a negative correlation between Sleep and DOMS. Figure 2 shows TC1. Only two *p*-values (September 20 and September 23) were significant when examining the relationship between sleep and DOMS, while two values were trending towards being significant (September 25 and September 28). These values coincided with the strongest negative correlation values that support the hypothesis.

Unlike TC1, there was a positive correlation between sleep and DOMS in thirteen of the fourteen days recorded in TC3 and all four weekly averages were positive. The *p*-values do not show any significance in TC3 and do not show any significant relationship. December 5 showed a trend in the opposite direction, which could be attributed to inaccurate data collection due to travel. Figure 3 is a graph of TC3.

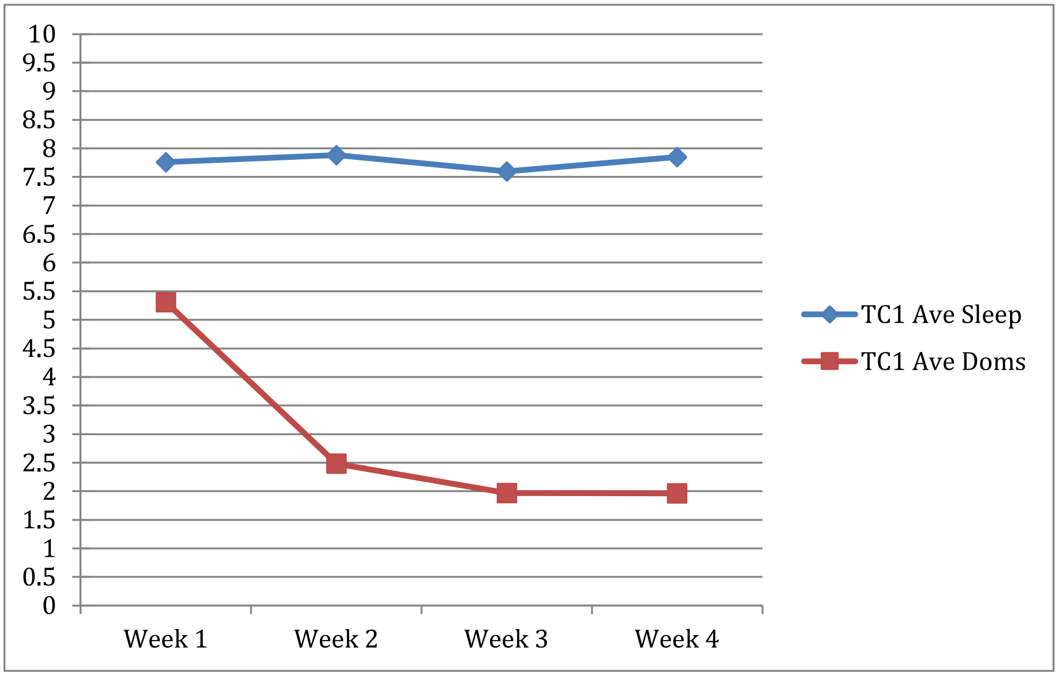

Figure 2. Graph of Weekly Averages of Sleep and DOMS during TC1.

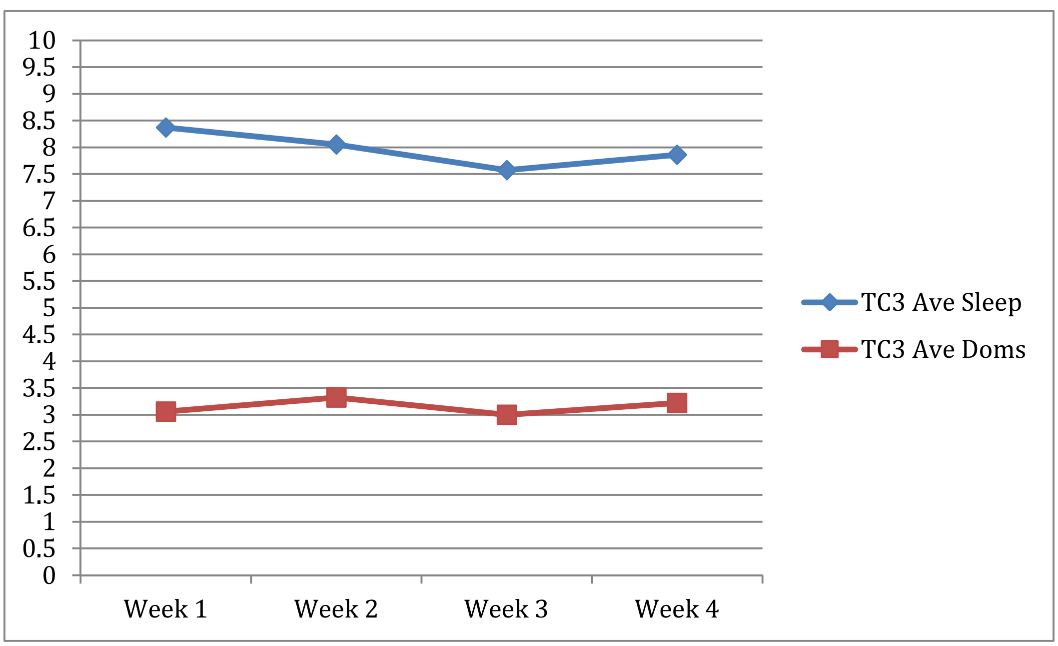

Figure 3. Graph of Weekly Averages of Sleep and DOMS during TC3.

CHAPTER III

DISCUSSION

The purpose of this study was to look at sleep and soreness in an athlete's typical training environment over an extended period of time. It was hypothesized that athletes who get more sleep would experience less delayed onset muscle soreness (DOMS) at some point during the training cycle With respect to sleep, week four of TC1 had the longest average sleep time of 7.85 hours while also having the least amount of DOMS at 1.96. All four weekly averages of sleep time in TCI were under eight hours of sleep and within a thirty-minute time frame (7.60-7.88), indicating participants were reporting comparable sleep times. Fourteen of the 16 days in TC1 were within one SD of the mean for sleep while all 16 days were within one to two SD for DOMS. In TC3, the SD for sleep increased in comparison to TC1, while the SD for DOMS decreased slightly compared to TC1. The standard deviations for sleep and DOMS show that participants were getting comparable amounts of sleep in TC1, but as the season progressed, participants reported varying amounts of sleep.

The *p*-value of the TC1 correlations showed that only two of the 16 recorded days (September 20 and September 23) had significant relationships, and two of those days (September 25 and September 28) were trending towards significance. None of the *p*-values in TC3 were significant, and even one *p*-value trending in the opposite direction, meaning a significant relationship has not yet been found.

Studies have shown that individuals overestimate their sleep time when sleep is self-reported (Girschik, Fritschi, Heyworth, & Waters, 2012.). Participants may also interpret soreness differently than others depending on training age and biological age and may not want to convey their soreness due to the competitive setting. In the first training cycle, the highest ratings for DOMS were in the beginning. Over time, as athletes became familiar with movements/exercises, the soreness was ameliorated. For TC3 though, soreness seemed to be consistent around a rating of three for the entire cycle. The consistency in soreness numbers could be attributed to similar movement patterns throughout the cycle, and no major changes were made in the intensity or volume of resistance training.

The most accurate way to collect sleep data is in a sleep lab. For the setting of this study, it was not practical to put athletes in training before an Olympic Games in that type of setting. When sleep is self-reported, on average, individuals (no professional athletes in this study) report getting 45 minutes more sleep than they actually got (Girschik et. al, 2012.) If that finding was applied to the data of this study, the weekly average of sleep would have dropped to less than seven hours of sleep for three out of the eight weeks, and less than eight hours of sleep for all eight weeks. This could potentially mean that the participants probably needed more time for rest and recovery from training. It would appear that sleep could have been more of a priority for the athletes. A way to help athletes get more rest is to have them stay in bed for a certain amount of time. This would help them extend their sleep. Mah et al. (2011), found that NCAA division I basketball players improved in all baseline tests, which included sprint times, free throw percentages, and three-point percentages by extending their sleep time over a 5-7 week period. The participants extended their sleep time by an average of 110 minutes per night (Mah et al., 2011).

The cohort did not attain large variances in sleep, which is necessary in order to support the hypothesis. Individuals would likely need less than six hours of sleep in order to experience a greater affect of DOMS compared to an individual who got an adequate amount of sleep. Too much sleep or prolonged supine positions could affect soreness due to venous pooling and decreased blood flow, which could affect the muscle's ability to recover (Brand, Dannenberg, Abbott, & Kannel, 1987). More research is necessary to determine if the relationship between sleep and DOMS is a reverse causality. Could an increase in DOMS decrease the amount of sleep an individual is able to get? Or could too much sleep or sedentary activities (sitting, standing, etc.) that increase venous pooling affect the muscle's ability to recover, thus increasing soreness? If that is to be the case, then a U-function could exist.

Further research is recommended in order to find the most accurate way to measure sleep without taking participants out of their training environment, but also being able to control settings in the environment. This could include a restricted sleep group, optimal sleep group, and sedentary group. All three groups would be on the same training program/physical regiment while sleep would vary between groups. A way to improve further studies and to keep participants in their normal environment and more cost effective is to use a FitBit or Polar device. They measure sleep, quality of sleep, and the number of awakenings or restless sleep during the night, but they do not measure time spent in different stages of sleep.

In conclusion, more research needs to be conducted in order to determine if sleep influences DOMS significantly in hockey players training for the Olympics. Although the data did not fully support the hypothesis, one could recommend that the participants may have needed more time to recover because two *p*-values showed to be significant. More research is also recommended to determine the type of relationship between sleep and DOMS.

APPENDICES

Appendix A

IRB Approval

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1322 Count Circle
Grand Forks, ND 58201

Dear Ms. Lamoureux:

We are pleased to inform you that your project titled, "Does Sleep Affect Delayed Onset Muscle Soreness (DOMS) in Olympic Hockey Players?" (IRB-201406-500) has been reviewed and approved by the University of North Dakota Institutional Review Board (IRB). The expiration date of this approval is July 3, 2015.

As principal investigator for a study involving human participants, you assume certain responsibilities to the University of North Dakota and the UND IRB. Specifically, any adverse events or departures from the protocol that occur must be reported to the IRB immediately. It is your obligation to inform the IRB in writing if you would like to change aspects of your approved project, prior to implementing such changes.

When your research, including data analysis, is completed, you must submit a Research Project Termination form to the IRB office so your file can be closed. A Termination Form has been enclosed and is also available on the IRB website.

If you have any questions or concerns, please feel free to call me at (701) 777-4279 or e-mail michelle.bowles@research.und.edu.

Sincerely,

Michelle L. Bowles, M.P.A., CIP
IRB Coordinator

MLB/jle

Enclosures

Appendix B

Consent From USA Hockey

Reagan Carey
Director, Women's Hockey
1775 Bob Johnson Drive | Colorado Springs, CO 80906-4090

June 20, 2014

Institutional Review Board,

I, Reagan Carey, Director of USA Women's Hockey for USA Hockey understand the involvement the players within our USA Women's National Hockey team will have in this study (that is being conducted by Monique Lamouruex) to look at data collected this year (2013-2014) looking at the athletes sleep and soreness. It is also my understanding that this information can only be published with consent from USA hockey.

With this understanding, I agree to have the members of our US Women's National Team player pool participate in this study and request that I be cc'd on any related communication to the team as it pertains to this study.

Reagan Carey

Appendix C

Workouts During Training

Day 1	WK1	Reps	WK2	Reps	WK3	Reps
DB Snatch	32	x5	35	x5	40	x5
MOB: Pec/Lat/	35	x5	40	x5	43	x5
Touch to Squat	40	x5	43	x5	48	x5
Yoga Table						
Circuit: Keiser x 2 sets 30/30 Format						
1/2 Kn. Anti-Rot. Pr	20					
FE Bosu Pushup	15					
X-Pulldown	20					
1 Leg Squat	10					
Tall Kneel Push/Pul	10					
Anterior Reach	10					
Landmine Press	10					
1/2 Kn. Chop	25					
1/2 Kn. Lift	20					
1/2 Kn. Bottom Up	10					
Suitcase Carry	Turf					
Sled Push	Turf					

Appendix C

Workouts During Training

Day 2							
Clean	Exp	Wk1 113	x5	Wk2 113	x5	Wk3 113	x5
		116	x5	120	x5	128	x5
		116	x5	120	x5	_____	x5
(think core stability and glute firing combined)							
Stability Ball Rollout		2	x12	2	x14	2	x16
Chinup		BW	x8	BW	x8	BW	x5
		BW	x8	8	x8	10	xmax
				6	x8	10	xmax-2
Rear Foot Elevated		BW	x8	BW	x8	BW	x8
Split Squat		113	x8	120	x8	140	x8
				100	x8	120	x8
Side Plank Row			x10x2		x10x2		x10x2
Circuit							
1 Leg Deadlift			x8		x8		x8
			x8		x8		x8
1 Leg SLDL		30	x8	34	x8	38	x8
			x8		x8		x8
1 Arm 1 Leg Row			x8		x8		x8
			x8		x8		x8
1/2 Kneeling			x8		x8		x8
Stability Lift			x8		x8		x8

Appendix C

Workouts During Training

Day 2							
Clean	Exp	Wk1 113	x5	Wk2 113	x5	Wk3 113	x5
		116	x5	120	x5	128	x5
		116	x5	120	x5	_____	x5
(think core stability and glute firing combined)							
Stability Ball Rollout		2	x12	2	x14	2	x16
Chinup		BW	x8	BW	x8	BW	x5
		BW	x8	8	x8	10	xmax
				6	x8	10	xmax-2
Rear Foot Elevated		BW	x8	BW	x8	BW	x8
Split Squat		113	x8	120	x8	140	x8
				100	x8	120	x8
Side Plank Row			x10x2		x10x2		x10x2
Circuit							
1 Leg Deadlift			x8		x8		x8
			x8		x8		x8
1 Leg SLDL		30	x8	34	x8	38	x8
			x8		x8		x8
1 Arm 1 Leg Row			x8		x8		x8
			x8		x8		x8
1/2 Kneeling			x8		x8		x8
Stability Lift			x8		x8		x8

Appendix C

Workouts During Training

Day 3				
CIRCUIT:10-lift	Circuit 1		Circuit 2	
Bench Press	96	10	120	5
RFE Split Squat	Warmup	10ea	61	5ea
Chin Up	BW	10	5	5
Trapbar Deadlift	Warmup	10	144	5
TRX Row	BW	10	10	max
Front Plank		10ea		10ea
Bench Press	96	5	120	5
RFE Split Squat	Warmup	5	60	5
TRX Row	BW	10		10
Trapbar Deadlift	Warmup	5	144	5
Side Plank		:30		:30
Bottoms Up Press		10ea		10ea

Appendix D

Dates of Recorded Data

Training Cycle 1				Training Cycle 2				Training Cycle 3			
Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4
9/10 **9/11** **9/13** **9/14** **9/15**	**9/17** **9/18** **9/19** **9/20** **9/21**	**9/23** **9/25** **9/28**	**9/30** **10/2** **10/3**	10/7 10/9		10/23	10/29 10/30 11/2	**11/12** **11/13** **11/14**	**11/18** **11/19** **11/20** **11/24**	**12/2** **12/3** **12/4** **12/5**	**12/9** **12/10** **12/14**

Training Cycle 4				Training Cycle 5			
Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4
12/16 12/17				1/6 1/8	1/16	1/20 1/22 1/25	1/30 1/31

Appendix E

Calendar View of Schedule

September 2013

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
TEAM CAMP (Fly back to Boston)	S&C: 9:30am (Lift 1) P:1:00pm -3:00pm	**P:10:30am -12:30am**	**S&C: 9:30am (lift 2) P: 1:00pm- 3:00pm**	**P: 10:30am - 12:30am**	**P: 10:30am - 12:30am**	**S&C: 11am (Lift 3)**
15	16	17	18	19	20	21
OFF	S&C: 9:30am (Lift 1) P: 1:00pm - 3:00pm	**P: 10:30am - 12:30am**	**S&C: 9:30am (Lift 2) P: 1:00pm- 3:00pm**	**P: 10:30am-12:30am**	**P: 10:30am - 12:30am**	**S&C: 11am (Lift 3)**
22	23	24	25	26	27	28
OFF (with Youth Hockey Clinic, tbd)	**S&C: 9:30am (Lift 1) P: 1:00pm - 3:00pm**	Arrive: 9:30am P: 10:30am - 12:30am	**S&C: 9:30am (lift 2) P: 1:00pm - 3:00pm**	Pre Game Skate 11am Game v U19 East Coast Wizards @ 7pm (location TBD)	Pre Game Skate 11am Game v U19 East Coast Wizards @ 7pm (the Edge)	**S&C: 11am (Lift 3)**
29	30					
OFF	**S&C: 9:30am (Lift 1) P: 1:00pm - 3:00pm**					

November 2013

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
					Pre Game Skate 9:00 am Ehibition Game v TBD @ 12pm (Location TBD)	**S&C:: 9:30am (Recovery) P: 10:30am - 12:30am**
3	4	5	6	7	8	9
TBD	S&C: 9:30am P: 10am - 12:00pm	P: 11am - 11:45am US v SWE @ 7pm (FOUR NATIONS)	P: 11am - 11:45am US v CAN @ 7pm (FOUR NATIONS)	OFF (FOUR NATIONS)	P: 11am - 11:45am US v FIN @ 7pm (FOUR NATIONS)	P: 11am - 11:45am Bronze @ 3:30pm / Gold @ 7pm (FOUR NATIONS)
10	11	12	13	14	15	16
OFF / TRAVEL	S&C: 9:30am (Lift 1) P: 1:00pm - 3:00pm	**P: 10:30am - 12:30am**	**S&C: 9:30am (Lift 2) P: 1:00pm - 3:00pm**	**P: 10:30am- 12:30am**	Arrive: 9:30am P: 10:30am - 12:30am	S&C: 11am
17	18	19	20	21	22	23
OFF	**S&C: 9:30am (Lift 1) P: 1:00pm - 3:00pm**	**P: 10:30am - 12:30am**	**S&C: 9:30am (Lift 2) P: 1:00pm - 3:00pm**	P: 10:30am - 12:30am	Pre Game Skate 11 am US v TBD @ 7pm (Location TBD)	Pre Game Skate 11 am US v TBD @ 7pm (Location TBD)
24	25	26	27	28	29	30
S&C: 11am (Lift 1)	P: 9:am-11:am	OFF / TBD	OFF	OFF	OFF	OFF

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