ATHLETES' SLEEP AND PERFORMANCE MEASURES DURING THE COMPETITIVE SEASON

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ABSTRACT

Athletes' Sleep and Performance Measures During the Competitive Season

Mariann Cristina Onofrio

Important information about the effect of sleep on sport-specific performance measures during different athletic seasons is lacking. Therefore, objective sleep and performance measures in football players were examined during two seasons. This was done using a single group, repeated measures design at a university lab and athletics practice facility. Twenty-four healthy male football players (age=21.6±1.6years, weight=99.7±18.9kg, height=183.8±5.6cm) participated in the study.

Participants wore a wrist accelerometer, *Actiwatch Score* (AS), during 5 days in the off-season and the in-season, with the last recording being the night before a game. Sleep efficiency (SE) and total sleep time (TST) were calculated using wake-quiet activity from AS. All athletes also completed a self-report measures sleep diary before bedtime and upon awakening. Performance measures, including: reaction time test, handgrip strength, vertical jump, and the agility t-test, were recorded at the end of 5 days during the off-season and on the morning of game day during the in-season.

There was no significant change in SE between off-season and in-season (77.6±7.2% and 77.5±7.9%, p=0.962). There was a trend toward an increase in in-season TST (375.2±70.2min and 409.3±72.4min, p=0.056). There was no

significant changes in performance measures between seasons (p values: 0.190 to 0.872).

There was no significant change in sleep measures between the off-season and in-season in university football players. However, the approximate 77% average of SE is alarmingly low. It is possible that student-athletes' rigid schedules contribute to their poor sleep. Future studies are needed to determine the cause of poor sleep in football athletes.

"Being a family means you are a part of something very wonderful. It means you will love and be loved for the rest of your life. No matter what." - Anonymous

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INTRODUCTION

Sleep is necessary for all individuals to be completely awake during the day and allow for optimal performance of daily activities.[1] Increased sleep quality and quantity can improve physical performance.[2] In today's population, average sleep time has decreased due to the demands of society.[1] In addition to shift-workers, Canadian students are compromising their regular amount of sleep.[3] Physical and cognitive performance are being jeopardized, as individuals opt to follow a sleep schedule that does not meet the body's sleep needs.[1] With decreased sleep, maximal exercise cannot be reached and a decrease in school and job performance also occurs.[2, 3]

Involvement in physical activity influences the amount of sleep an athlete gets.[2] With exercise, circadian rhythm changes in period, phase and amplitude.[4] The biological rhythm of an athlete is better synchronized compared to a sedentary individual and the amplitude is more consistent; therefore, the circadian rhythm of a high level athlete differs from a sedentary individual.[2] While the light-dark cycle significantly influences the general population's amount of sleep, exercise might temper the cycle's role; therefore, the level of physical activity may change the effect of environmental light posed on sleep parameters.[2] Exercise may have an effect on variables that affect sleep, such as anxiety, therefore we are interested in all variables that affect sleep and consequently performance in the athletic population.

There is reason to believe that an athlete's total sleep time can affect physical performance.[5] Sleep and exercise are interconnected; increased sleep allows for better sports performance and increased activity level increases sleep.[2] Unfortunately, varsity athletes are exposed to extreme levels of stress and performance, as training and competition cause changes in regular schedules, therefore affecting athletes' sleep-wake schedules.[6] Sleep loss in athletes causes a general decrease in performance, namely psychomotor and cognitive function.[2] While light-dark cycles and stressful schedules may cause a decrease in physical performance, regular exercise can regulate the dysrhythm of circadian rhythm.[2]

Important information about the effect of sleep on sport-specific performance measures during different athletic seasons is lacking. A study looking at young female adults suggested that sleep directly affects performance, yet only subjective sleep measures were collected, therefore more objective research is needed to directly measure sleep and performance.[5] Moreover, two studies with rugby and football correlated sleep and performance and measured performance by whether or not they won the game.[7, 8] Using wins and losses as a basis for performance is limited because the win or loss could be due to a variety of other variables that affect the contest outcome. In addition, other studies that looked at athletes and performance entailed sleep deprivation compared to baseline, which is not representative of an athlete's in-season sleep schedule. Therefore, as there is a lack of regular baseline and in-season objective sleep and performance data, the purpose of our study was to objectively measure veteran and/or starting athletes‘ sleep and performance in and out of season. We hypothesize:

A) a decrease in objective and subjective sleep measures in the in-season compared to the off-season

B) A decrease in objective and subjective sleep measures the night before a game in-season

C) A decrease in performance measures in the in-season

D) A decrease in in-season and night before the game sleep measures would negatively affect performance measures.

LITERATURE REVIEW

Sleep Measures

Polysomnography, which is a sleep measurement device, done in a laboratory setting is the gold standard for diagnosing sleep.[9] This testing method collects data about oximetry (the amount of oxygenated blood), airflow, changes in heart rate, snoring, movement of the abdominal area, and electrical activity through electroencephalography and electromyogram.[9] This method of recording sleep data is very costly, due to the expensive equipment and the necessity of a laboratory setting and laboratory technicians to monitor subjects.[10]

For the purpose of this study, actigraphy will be used to measure sleep data. The actigraph is a wrist-worn device that contains an accelerometer that records movement throughout the day.[11] By comparing the amount of movement to the amount of lack of movement, also known as sleep in actigraphy data collection, we can estimate a multitude of sleep-wake measures.[12] Actigraphy correlates well with polysomnography, in measuring sleep parameters.[13, 14] More specifically, the Actiwatch Score (AS) (Actiware and Actiware CT, Respironics, Inc., Murrysville, PA) model has shown to have very good interunit reliability when worn on the non-dominant wrist, providing reliable and comparable data for sample sizes using more than one AS for data collection (r=0.98).[15] Also, this reliability has been shown to be constant over long periods of time, as the mechanical sensitivity of the actigraph does not significantly change.[14] Unlike polysomnography, actigraphy does not cause the “first night” effect, which is a decrease in overall sleep on the first night of data collection, in a healthy population that is not suffering from sleep problems.[14]

Measures of sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO) and sleep efficiency (SE) can be extrapolated through the AS.[11, 12] Sleep onset latency (SOL) is defined as the amount of time an individual takes to fall asleep after going to bed, measured by immobility.[13] Total sleep time (TST) is the amount of time spent sleeping during the sleep interval, from bedtime to wake up.[14] Wake after sleep onset (WASO) is categorized as the time spent awake after falling asleep until the final awakening.[16] Last, sleep efficiency is a percentage representing how well an individual slept from sleep onset until final awakening.[12] In other words, sleep efficiency represents the total sleep time achieved compared to the time from sleep onset to final awakening.[12]

While actigraphy has been validated in healthy populations, certain procedures must be followed in order to prevent erroneous data collection.[13, 14] A fact of great importance when analyzing sleep measures is that actigraphy is less accurate than polysomnography in recording SOL and total wake time.[13] For this reason, the use of a sleep diary to note measures such as bedtime, wake-up time, naps and time that the AS was removed for bathing purposes is of importance.[14] While some research shows that the placement of actigraphy on the dominant and non-dominant wrist has no effect on sleep duration and activity measures, other research states that the actigraph must be worn on the non-dominant wrist, as the dominant wrist records higher amounts of activity.[13, 14]

As aforementioned, a sleep diary is necessary to be used in conjunction with actigraphy.[14] The Pittsburgh Sleep Diary (PghSD) is an instrument that measures daily activities and perceived sleep measures.[17] These measures include: sleep duration, WASO, sleep quality, waking mood and alertness.[17] The diary must be filled out twice daily; once before bed and once upon awakening.[17] The PghSD is very reliable, with a high inter-test correlation.[17]

Questionnaires

Questionnaires have been formulated and validated in order to measure self-report sleep measures and receive subjective information from participants about their sleep.

The Epworth Sleepiness Scale (ESS) is a questionnaire used to measure an overabundance of sleepiness and daytime sleepiness.[18] The questionnaire includes eight different scenarios and the subject rates how likely they are to fall asleep on a scale of 0, representing never dozing, to 3, representing a high possibility of dozing.[18] A summation of the responses equating to 9 or more signifies that the individual is very sleepy and needs medical advice.[18] The ESS has high validity, reliability and internal consistency.[19] In Fietze et al.'s study looking at professional ballerinas' sleep quality, the ESS was used to measure the ballerinas' sleepiness throughout the test period; the authors noted that sleepiness increased as physical health decreased, according to the SF-12, which is a physical and mental health survey.[6]

The Pittsburgh Sleep Quality Index (PSQI) assesses an individual's sleep disturbances and sleep quality.[20] The questionnaire analyzes sleep quality, sleep duration, sleep efficiency, sleep disturbance, sleep medications and daytime dysfunction.[20] The components of this questionnaire enable the researcher to distinguish between good and poor sleepers.[20] The PSQI is very reliable, with a reliability coefficient of 0.83.[20] Overall, the PSQI is a good tool to use to distinguish between good and poor sleepers, scores ranging from 0 to 21 and a score of more than 5 categorizing bad sleep.[20]

The SF-12 Health Survey is a shorter version of the original 36-question SF-36 Health Survey that can be completed in 2 minutes or less.[21, 22] Questions about physical health and mental health chosen from the SF-36 Health Survey make up the 12 items of the questionnaire.[21] The SF-12 correlates highly with the original and longer version in both physical and mental questions.[21, 22]

The Beck Depression Inventory (BDI-II) is a 21-item questionnaire used to determine an individual's intensity of depression.[23] Each item is rated from 0 to 3, 0 representing no symptoms or attitudes of depression and 3 representing constant symptoms or attitudes of depression.[23] The BDI has high internal consistency, stability, construct validity and test-retest reliability.[23]

The Seasonal Pattern Assessment Questionnaire (SPAQ) was created to measure seasonal affective disorder (SAD) among people.[24] Moreover, seasonal mood and vegetative functions are also measured.[25] The questionnaire must be completed during the summer months alongside a depression scale questionnaire, such as the BDI.[24] Questions about demographics, seasonal changes in sleep parameters, mood, weight, appetite and social activities are included in the SPAQ.[25] While the SPAQ has excellent specificity and good internal consistency, this questionnaire is to be used only as a screening tool and not as a diagnostic one, because of a lack sensitivity.[24]

General population's sleep and performance measures

The amount of sleep an individual gets can affect both physical and cognitive performance.[26] Over the years, fatigue has increased, as people jeopardize their sleep hours for daytime activities.[1] With a lack of sleep, alertness will decrease and may cause detrimental reductions in productivity.[26] Decreased alertness can occur in occupations that involve shift-work, as these workers' top health-related side effects are sleep disturbances.[27] Alongside shift-work, decreased sleep is also common among Canadian students.[3] With a decrease in sleep, an increase in human error, including industrial accidents, exists.[1]

A previous study has noted the danger of completing regular shift-work in many professions including commercial bus drivers.[28] Through the use of self-report questionnaires, bus drivers within a 30-mile radius of Edinburgh, Scotland, reported daytime sleepiness, sleep disorders and symptoms, and work accidents.[28] Of the 677 drivers analyzed, 12% claimed that they fell asleep at the wheel at least once per month.[28] Of those who fell asleep at the wheel, more than half reported being in an accident due to sleepiness.[28] These results demonstrate the importance of sleep and the danger encompassing lack of sleep caused by the required shift-work of this occupation.[28]

Moreover, irregular shift work in train drivers and traffic controllers has an effect on their sleep-wake rhythm.[29] Prior to this study, while regular shift-work has been studied, irregular shift-work schedules have not. The researchers collected data through the use of a diary during a three-week period; 126 train drivers and 104 traffic controllers were analyzed.[29] Through the analysis of the participants' diaries, the researchers noted a decrease in sleep time before morning and night shifts.[29] Also, 65% of nightshift workers had an afternoon nap averaging 2 hours and 20 minutes.[29] Dozing off was also seen in 24% of night shift workers, occurring at approximately 3:00am, but this dozing was not the case in morning shifts.[29] Sallinen et al. concluded that the combination of shifts need to be better scheduled in order for individuals to have better sleep schedules and fulfill the amount of sleep needed to properly function.[29]

In an in-depth review completed by Torbjörn Åkerstedt, the effects of morning, afternoon and night shift work are described.[27] Those who work the night shift commence sleep 30 to 60 minutes after their shift is finished, but their total sleep time is reduced by 2-4 hours.[27] This sleep pattern causes the night-shift workers to feel like they did not get enough sleep.[27] Unfortunately, these workers awake very easily, therefore about 33% rely on taking a nap in the afternoon, caused by their constant subjective and objective sleepiness.[27] On the opposite side of the spectrum, morning shift workers must sleep at night and have difficulty doing so.[27] Their total sleep time is usually short, averaging 6 hours and their anticipation of early wake up causes a decrease in slow wave sleep.[27] Also, the workers have a lot of difficulty waking up and do not feel refreshed at wake-up time.[27] Overall, shift work affects overall sleep patterns and levels of fatigue, and a consistent theme among the different types of shift workers is the taking of a nap during the day to help reduce sleepiness.[27]

Among the previous data collected in shift-workers, a consistent theme can be noted. Both studies base their findings solely on subjective data. While daytime sleepiness and number of accidents can be reported through questionnaires, objective sleep-wake schedules could be further studied to better analyze the time spent awake and asleep. More objective data needs to be presented in shift-workers and resolutions to shift alertness and productivity needs to be developed. Also, as presented in the review, more data collection about the pros and cons of daytime naps need to be studied.

Pain affects sleep in the general population

Sleep changes have become an important characteristic of individuals suffering from pain.[30, 31] As these individuals experience pain, their function and sleep patterns are altered.[30, 31] As pain increases due to chronic low back pain or bruxism, sleep is obstructed, consequently affecting one's mood.[30, 31] While there is a lack of research in this domain, a few articles briefly mention the effect of sleep on injury rehabilitation and pain in chronic disorders.

In a presentation of shoulder impingement syndrome, the effect of shoulder pain on sleep is mentioned.[32] A total of twenty-eight patients had athroscopic debridement of the shoulder; twenty-two returned to play, but twenty individuals still had unknown pain while playing.[32] Details about pain and sleep are not well defined, but the authors do also mention that shoulder pain will affect sleep, causing awakenings during sleep time.[32]

An area of research that focuses greatly on pain and sleep is that of sleep bruxism. Sleep bruxers who have a decreased frequency of orofacial activity at night have more pain on awakening.[33] Through the use of questionnaires completed during screening and recording sessions, the authors noted that the aforementioned sleep bruxer group had more pain and fatigue in the jaw on awakening, possibly due to their higher levels of stress, nervousness and fatigue prior to data collection.[33] Overall, sleep is negatively affected by stress and nervousness, causing for the pain of bruxism to be more notable in this group.[33]

While general information exists on the idea of pain's effect on sleep, there is a lack of research with regards to the general population and their sleep patterns due to acute and chronic pain. While the extent of one’s pain can only be gathered objectively, correlating this night pain and day pain data to subjective and objective data can present many interesting ideas.

Exercise and sleep

Exercise has a positive effect on sleep. With an increase in physical activity among adults and the elderly, sleep disturbances decrease, allowing for a better sleep quality.[5] Exercise has many benefits to different aspects of sleep; with an increase in physical activity, the strength of circadian rhythm is increased and sleep onset latency and sleep fragmentation are decreased.[2] Also, prior to using pharmacological interventions to increase sleep, exercise is prescribed, as better sleep parameters exist among the athletic population versus sedentary individuals.[34]

Sleep patterns were compared in soccer players and their non-athlete counterparts, showing better sleep patterns and psychological function among the athletic group.[35] Thirty-six teenage male soccer players were matched with thirty-four non-athletes from the same school to control for daily schedules.[35] A sleep log, adapted from a German version of the Pittsburgh Sleep Quality Index questionnaire was used for a period of 7 days.[35] The participants filled out the sleep log twice a day, which contained questions based on an eight-point visual analogue.[35] Sleep parameters such as day sleepiness, daily concentration and mood at bedtime were asked at night and sleep quality, awakening mood, restorative feelings, sleep onset latency, number of awakenings and total sleep time were asked upon awakening.[35] Overall, the authors found that the athletic group had better subjective sleep during school and off-school nights.[35]

While Brand et al.'s study presents valuable information, incorporating objective sleep measures would aid in solidifying some of their results, including sleep onset latency and total sleep time. The presumption exists that exercise benefits sleep parameters, but research is scarce, therefore more research needs to be done in this domain in order to support this claim.

Athletes' sleep and performance measures

Athletic populations are proposed to have better sleep parameters when compared to the regular population; therefore suggesting that exercise can help improve sleep.[34] Alongside sleep being important in the general population to be able to function and perform during activities of daily living, sleep also has an effect on many systems in the athlete body.[5]

AJY Lee and WH Lin studied sleep quality and physical fitness in young female adults.[5] While the 291 college aged females from Taiwan simply used the Pittsburgh Sleep Quality Index questionnaire to measure sleep quality, their physical fitness was tested through the use of a battery of physical tests including: BMI to measure body composition, the sit-and-reach test to measure flexibility, the curl-up test to measure muscular strength and endurance and the 800 meter run or walk test to measure aerobic capacity.[5] The authors concluded that a decrease in flexibility, muscular endurance and cardiovascular fitness was present when the females' sleep quality was compromised.[5]

Lee and Lin's study looking at females' fitness and sleep measures requires more data collection. While the use of the Pittsburgh Sleep Diary is a necessity, collecting objective sleep measures may be valuable in future studies. In order to look at the relationship between sleep and performance measures, direct correlations need to be made, and objective sleep measures can facilitate this correlation.

Athletes' performance following sleep deprivation

Sleep deprivation, which ranges from a decrease in a few hours to a few days of sleep, and physical performance testing is very popular, as many studies exist in this domain.[36-40] While sleep deprivation rarely occurs by choice among student-athletes, their schedules sometimes cause for this inconvenience.[6] Sleep deprivation causes a decrease in all domains of athletic performance.[2, 36-40]

The effect of sleep deprivation on anaerobic performance in physically active individuals has been studied.[36] The subjects underwent both protocols, which were completed one week apart; the first one allowed the participants to sleep the night before testing and the second condition caused the subjects to be deprived of sleep, remaining awake overnight.[36] The following day, physical performance was tested at 6:00 am and 6:00 pm.[36] Force-velocity testing and the Wingate test were used to test maximum power, peak power and mean power.[36] Blood lactate concentrations were also analyzed through blood samples taken at rest, at the end of the force-velocity testing, and before, after and 5 minutes after the Wingate test.[36] Overall, anaerobic performance was unchanged following 24 hours of sleep deprivation, but decreased in all three categories following 36 hours of sleep deprivation.[36]

Cognitive and motor performance have also been looked at in sleep deprived individuals.[37] Six 22±0.3 year old male students underwent a cross over design procedure, where both experiments called for 30 hours of sleep deprivation; in one group, the participants completed 20 minutes of intermittent cycling every 2 hours at 50% of their VO_{2peak}; the other group performed sedentary activities at those times.[37] Those who remained sedentary throughout the 30 hours saw a decrement in their reaction times of simple and two-choice tasks.[37] The reaction times of subjects during their submaximal exercise were lower than those recorded when sedentary.[37] The authors state that the exercise is not the cause of decreased activation and performance, but the exercise rather acts as a distraction to the subjects.[37]

The relationship between sleep deprivation and the cardiorespiratory system has been studied in athletes.[38] Ten teenage male middle distance runners and ten teenage male volleyball players participated in this study where their resting spirometric and cardiopulmonary exercise tests were completed after a normal night of sleep and after one night of no sleep.[38] The findings showed that time to exhaustion and minute ventilation is decreased after only one night of sleep deprivation.[38] Also, resting VO_2 in runners increases and resting VCO_2 increases in runners and volleyball players after 25 to 30 hours of sleep deprivation.[38] Time to exhaustion and maximal exercise are decreased because energy levels are decreased with sleep loss.[38] Sleep loss does not change exercise heart rate, VCO_2 and respiratory quotient (R).[38]

Sleep deprivation was once more looked at in eleven males who were recreationally active and healthy.[39] Oliver and colleagues compared treadmill exercise after a normal night of sleep to after a night of sleep deprivation.[39] The following morning, the participants reported to the laboratory, where they completed 30 minutes of endurance running on the treadmill.[39] Objectively, the participants covered less distance when sleep deprived, but there was little change in pacing, cardiorespiratory, thermoregulatory and effort perception after 30 hours of sleep deprivation.[39] Subjectively, the participants had the same perceived effort in both trials, therefore their perception of effort can be altered with lack of sleep, causing decreased performance.[39]

Compared to the customary 30 hour sleep deprivation induced in studies, Lucas and colleagues decided to study the effect of 100 hours of sleep deprivation due to continued exercise.[40] Participants completed 96 to 125 hours of racing without sleep.[40] The authors showed that while complex decision making was impaired during the race, physical capabilities only had a modest decrease.[40] The authors also state that motivation causes a decrease in exercise performance while sleep deprived.[40]

While Souissi et al.'s main purpose was to study the effect of sleep deprivation on anaerobic performance in healthy, active individuals, comparing these results to a non-active group would have been interesting. Moreover, while Scott et al., Azboy and Kaygisiz, and Oliver et al.'s main purposes were not to collect sleep data, but solely to report the differences in performance in regular sleep versus no sleep, I believe that the use of actigraphy is necessary. Individuals do not have the same sleep patterns and therefore while the subjects were allowed to sleep a full night's rest during one of the data collection sessions, looking at values such as sleep efficiency, sleep onset latency, wake after sleep onset and total sleep time is important. These values will create a clearer relationship between sleep versus no sleep and their effect on performance.

Athletes' sleep and somatosensory changes

With decrements in sleep come feelings of fatigue and altered mood.[41] Sleep deprivation is a major contribution to overtraining and can also increase the risk of minor injuries.[41] Moreover, sleep efficiency has been shown to be a predictor of overreaching.[42]

Sleep and psychological measures were recorded in a group of forty-three Australian Army Recruits over a 5-week period.[41] Throughout the 32-day span, fitness testing occurred on day 3, 18 and 32.[41] Concurrently, a sleep and health diary was kept daily and psychological questionnaires were completed on the same day of the week, throughout the 5-week span.[41] Hours of sleep, hours of wakefulness, sleep quality, on a 7-point scale, and a health checklist made up the sleep and health diary.[41] The psychological questionnaires included the Multidimensional Fatigue Symptom Inventory - Short Form and the Profile of Mood States questionnaire.[41] As symptoms of overtraining became apparent, the army recruits' sleep diaries stated that their sleep quality remained the same over the course of the training period, but their sleep times decreased and consequently their positive mood decreased and their general and physical fatigue increased.[41] Therefore, with sleep deprivation being categorized as a major contribution to overtraining, leading to further sleep disturbances, mental fatigue, decreasing friendliness and high levels of confusion, athletes can suffer both physically and mentally.[41]

Also, nine swimmers' sleep efficiency and swim times were studied.[42] Actigraphy was used to measure sleep over a 24-hour period.[42] Two days of recordings were collected; 1 day before the first week's swim trial and 1 night after the fifth week's swim trial.[42] Overall, the authors noted that the number of movements during sleep increased as training volume increased.[42] Overreached swimmers are categorized as those who have more than a 5% performance loss after 2 or more consecutive attempts.[42] When comparing the overreached to the non-overreached participants, there was a significant difference between sleep efficiencies.[42] Moreover, a correlation between training load and mood disturbance exists.[42] As training loads increase, mood decreases according to the Profile of Mood States (POMS).[42]

Overall, Booth et al.'s study provided very interesting information, as psychological, physical and sleep testing were all combined. Incorporating objective sleep data would benefit the study, as the authors believed their sleep quality measures to be inaccurate since the values stayed the same as hours of wakefulness increased.[41] Wall and colleagues' study showed a clear connection between all variables and presented both subjective and objective data, making the idea of subjective and objective sleep collection useful.[42]

Athletes and jet lag

Jet-lag occurs when traveling through time zones, causing a shift in circadian rhythm, also known as the body clock.[43] As the number of time zones being crossed increases, so too does the severity of jet-lag.[43] Traveling across time zones has an overall negative effect on individuals, as peak performance is difficult to attain and motivation to train lacks.[44] When the body clock is desynchronized, sleep loss occurs, resulting in a decrease in performance.[45] Reilly and colleagues mention that the effect of jet-lag differs only slightly among people, with physical fitness being an attribute to this difference.[43] With an increase in physical fitness, mental toughness and sleep-promoting effects are increased, allowing for the ability to cope with the desynchronization of the body clock, which is calculated as the time change caused by travel.[43]

In a group of eighteen male marathon runners, actigraphy was used to study their readjustment following a transcontinental flight.[46] The runners were divided into three groups and followed three different protocols prior to leaving from Milan to New York for their marathon.[46] Twelve of the eighteen runners followed a 3-day a week running program for one month prior to their flight, while the remaining 6 did not partake in the running program or the marathon.[46] The morning training group ran from 7:00am to 9:00am, while the evening training group ran from 7:00pm to 9:00pm.[46] The authors noted that exercise before transcontinental flights betters the adaptation to the new time zone.[46] More specifically, exercise improves sleep quality and helps resynchronize after a flight.[46] The evening training group had better sleep quality and less fragmentation after the flight.[46] The morning training group showed improved sleep quality compared to the control on the second night in New York.[46]

In a group of elite Australian Rules football players, sleep quality and quantity prior to a game were measured to examine how they were affected by interstate travel.[7] Compared to baseline, the athletes' sleep times increased on the night before their game, but their perceived sleep quality decreased.[7] The authors suggest that this increase in sleep time may be due to the athletes' discipline and proper preparation for a game, by incorporating a good night's sleep prior to competition; their age and fitness level may have also helped in readjusting their circadian rhythm at a quicker rate.[7]

Overall, both studies show a relationship between traveling and its effect on the sleep schedule. Although the studies focus on perceived sleep quality, the use of actigraphy in Montaruli et al.'s study to monitor sleep efficiency, total sleep time, sleep onset latency and wake after sleep onset would be interesting to analyze. Moreover, although Reilly and colleagues conclude that mental toughness is related to performance, a lack of details exists on the method of measuring mental toughness. This variable of mental toughness could be of interest to identify in future studies.

Athletes and performance

Athletic performance is what sets apart one athlete from the next. Maintaining proper sleep habits is one variable that can help in promoting optimal performance among this population.[2] While exercise positively affects quality of sleep, sleep time has been shown to decrease in athletes versus non-athletes in the student population.[47] Prior to competitive events, athletes have a hard time initiating and maintaining sleep.[47] With sleep deprivation, reaction time and cognitive and motor performance are decreased.[47] Unfortunately, there is a lack of research in the domain of athletes and their performance on game day. Performance among football and rugby players and ballet dancers has been looked at, yet objective data is lacking.[6-8]

The performance of East and West Coast NFL teams was studied during Monday Night Football games.[8] Performance was measured by wins and losses.[8] A retrospective analysis of the last 25 seasons was done, showing that the West Coast teams won more games and with more points compared to the East Coast teams.[8] The authors concluded that a circadian rhythm of athletic performance exists, showing an advantage at certain times throughout the day.[8]

Next, sleep patterns and interstate travel among elite Australian Rules footballers was studied.[7] Ten athletes from the Western Australian-based Australian Football League participated in this study.[7] Through the use of actigraphy and sleep logs, sleep quality and quantity were recorded throughout the season.[7] When comparing sleep and performance in home games versus away games, the authors gathered that traveling over 2 time zones had no adverse effects on the sleep patterns of the players on the night before a game.[7] The data actually showed that players slept more on the night before a game compared to baseline and fewer awakenings were noted the night before an away game.[7] When looking at the performance of the players, based solely on wins and losses, performance decreased with travel, as the team lost 7 out of 8 away games.[7] Therefore, traveling across time zones does not have an affect on sleep measures, but causes changes in performance.[7]

Last, professional ballerinas' sleep quality was studied throughout a season.[6] Objective and subjective data from wrist actigraphy and sleep diaries were collected from 24 classical ballet dancers over a 67-day period.[6] Subjects with substance abuse of alcohol, medication and drugs were excluded from the study, as sleep parameters are altered by these activities.[6] Overall, total sleep time and sleep efficiency decreased significantly during the study as the ballerinas approached performance day.[6] Also, wake after sleep onset increased during the week prior to the show's premiere.[6] Subjectively, sleep quality, based on a 3 value score, was unchanged throughout the study.[6] The authors believe that an increase in physical and mental stress may have caused changes in sleep efficiency, sleep duration, time in bed and wake after sleep onset as the ballerinas approached the day of their premiere.[6]

A consistent lack of objective performance data is lacking in all three studies. In the case of the NFL and rugby studies, performance cannot be solely based on wins and losses; a more valid and reliable measure of performance is necessary. Fietze et al.'s study looking at ballet dancers provides interesting information, but the inclusion of objective performance measures throughout the data collection would help improve our understanding of the link between sleep and performance.

Performance measures

As noted in the previous section, performance cannot be measured by wins and losses; valid measures of performance are necessary. Strength, speed and power are components of performance that divide starters from nonstarters in football teams.[48] With regards to grip strength, while there is no reference that I could find that correlates handgrip strength to football performance, handgrip strength is a valid and reliable measure and 5 studies using football athletes have included this measure in their results.[49] Next, the vertical jump is a valid test that discriminates starters from nonstarters in College American Football.[48] Also, the NFL combine uses the vertical jump as one of their tests, and correlations between high vertical jumps and quarterbacks being drafted earlier on is seen.[50] While no studies correlating the agility t-test to football performance were found, this test incorporates the testing of agility, leg power and speed, components that separate starters from nonstarters in football teams.[48, 51] Last, reaction time is of importance in all sports, including football, as reaction time is a valid measure in testing severity of a concussion, an injury that disallows participation in physical activity; therefore, reaction time can be categorized as a measure readiness for return to sport.[52]

Grip strength is best evaluated using a handheld dynamometer, namely the Jamar hydraulic hand dynamometer (J.A. Preston Corporation, Clifton, NJ), which is the gold standard measuring device for individuals aged from 20 to 50 years.[53] The Jamar dynamometer’s test-retest and interrupter reliability is good to excellent (r=0.88 to 0.99).[49] While research shows that elbow positioning during testing does not affect strength in the adolescent population, other research states otherwise.[54] The American Society of Hand Therapists recommend that subjects are seated, with their dominant arm along their torso, elbow at 90 degrees of flexion, forearm in neutral, wrist at 30 degrees of extension and no radioulnar deviation.[55] Three maximal measures of handgrip will be taken for 6 seconds, with 1-minute rest between bouts.[56, 57] The maximum value recorded in the three trials is recorded and used for data analysis.[55, 58] This method of collection has high repeatability.[55] Also, studies have suggested that handgrip tests be performed after 10am because early morning has a negative effect on performance.[59] The time used for testing should also remain constant between trials, as to reduce diurnal variations.[59]

Vertical jump is a good measure of power and performance in athletic populations, including football players.[60, 61] Vertical jump height testing has a high test-retest reliability (r = 0.95 to 0.97).[62] The Vertec vertical jump tester (Sports Imports, Hilliard, OH, USA) is the measurement of choice, as this apparatus is highly correlated with the 3-camera reference system.[63] The Vertec is very dependent on subject and examiner accuracy.[63] The subject needs to be free of shoulder limitations and must be able to hit the vanes at the peak of his jump.[63] Also, the examiner must accurately determine the start position and be able to properly count the number of vanes that have been hit.[63] Previous procedures recommend that subjects stand with their dominant hand on the same side of the Vertec vertical jump tester.[60] Prior to the subject’s vertical jump, having the subject raise his hand straight up in order to adjust the Vertec’s base marker to this height is a necessity.[60] Also, the subjects are not allowed to take a preparatory step, but arm swings can be used prior to jumping.[60] Next, subjects will be cued to jump and hit as many vanes as possible.[60] Three countermovement jumps will be performed, with one-minute rest periods between trials.[60] After the 3 trials, the highest jump height will be used for data analysis.[58, 60]

The agility t-test is a measure of leg speed, power and agility.[51, 64] Also, the agility t-test shows differences between low- and high-level sport participation.[51] The test has an excellent intraclass reliability (r = 0.98).[51] To properly reproduce the test, a hardwood gymnasium floor should be the surface of choice.[51] Next, subjects need to warm-up prior to the completion of the agility t-test.[51] The test consists of running forward for 10 yards, touching the cone, shuffling left for 5 yards, touching the cone, shuffling 10 yards to the right, touching the cone, shuffling left for 5 yards, touching the cone, and finally running backwards for 10 yards.[51, 64] Prior to completing the test, participants can perform up to two submaximal trials.[64] Three maximal trials are necessary, recording the fastest of the three.[51]

Last, reaction time testing using a measuring stick is a valid measure of reaction time in the football population.[52] Reaction time is directly affected by sleep deprivation; as an individual becomes sleep deprived, his or her reaction time is compromised.[65, 66] In a pilot evaluation completed by Eckner and colleagues, 91 Division 1 football players participated in the trial.[52] The clinical reaction time test, using a 1.3 meter long measuring stick with high-friction tape and 0.5 centimeter increments, was studied to compare its results to those received from a computerized neuropsycholgical test that has been validated.[52] A positive correlation between clinical and computer reaction times is present, but more consistent baseline reaction time values are seen with the clinical reaction times.[52] The athletes in the trial were seated with their right forearms resting on a table and their hands resting on a rubber disk attached at the end of the stick.[52] Ten trials, including 2 practice trials, were completed, where the examiners released the stick at predetermined and randomly assigned times between 2 and 5 seconds.[52] The distance (d) from the top of the disk to the most superior part of the athlete's hand is measured and then converted to time, using the formula $d=0.5gt^2$, where g is gravity and t is time.[52]

With the use of these performance measures, objective performance scores surrounding important aspects of game day performance will be collected.

METHODS

Research Design

To identify if starting athletes’ sleep is negatively affected in season, we conducted a longitudinal prospective study during the pre-season and in-season time of the year. Athletes’ sleep measurements and performance measurements were recorded during the summer pre-season (July-August) and in-season (September-November).

Subjects

Thirty-seven subjects from the Concordia University varsity football team participated in the study, 24 of which were analyzed (age=21.6±1.6years, weight=99.7±18.9kg, height=183.8±5.6cm). We used football athletes because the games are always on Saturdays, allowing for the 5 days of sleep collection between competitions to be consistent. Veteran and/or starting athletes who were aware of their position on the depth chart were included, as their performance measures differ from non-starters.[48, 67] Subjects were excluded from the study if they regularly consumed alcohol or recreational drugs for the duration of the study and if they had any medical conditions, as these factors have been shown to affect sleep.[68]

Measures

Sleep

We used actigraphy to objectively measure sleep in the athletes.[11] All participants wore the *Actiwatch Score (*AS*)* (Actiware and Actiware CT, Respironics, Inc., Murrysville, PA) on their non-dominant wrist.[13-15] While wearing the AS, participants were instructed to follow their regular daily routine, however they were instructed not to consume alcohol or drugs.[6, 68] They also removed the AS when bathing or during contact sports, since water or high impacts can damage the accelerometer.[17]

Questionnaires/Journals

We used the SF-12 Health Survey to measure the participants' general physical and mental health.[21, 22] We also administered the Pittsburgh Sleep Quality Index (PSQI) questionnaire to gather information about the participants' sleep hygiene, a score above 5 showing poor sleep quality.[20] The Epworth Sleepiness Scale (ESS) questionnaire allowed us to look at the participants' daytime sleepiness, where a score of 9 and above shows above average daytime sleepiness.[18, 19] Next, we used the Beck's Depression Inventory (BDI-II) questionnaire to investigate the participants' level of depression, showing clinic concerns with scores above nine.[23] We measured seasonality using the Seasonal Pattern Assessment Questionnaire (SPAQ).[24, 25] Also, the players' chronotypes were measured using the Morningness-Eveningness Questionnaire.[69] Last, the players' anxiety levels, both as a trait (STAI-T) and as a state (STAI-S) were measured; we measured STAI-T only once at the beginning of the study, whereas the STAI-S questionnaire was given to athletes to complete every day during data collection.[70]

The athletes were given the Pittsburgh Sleep Diary, which was used as a journal; the morning sheet included questions such as bedtime, sleep time, minutes taken to fall asleep, number of times woken up throughout the previous night, minutes awake after sleep onset, reasons for wake, wake up time, method of wake up, and ratings of sleep quality, mood, alertness, fatigue, night pain and present pain.[17] The bedtime sheet included meal times, the amount of caffeine and cigarettes and when, the use, time and dose of medications, exercise type and amount, length of naps, and the removal of the actigraphy device for bathing purposes or during contact sports.[17]

Performance

We measured grip strength using a Jamar handheld dynamometer (J.A. Preston Corporation, Clifton, NJ) (see figure 1).[53] We instructed the subjects to be seated, with their dominant arm along their torso, elbow at 90 degrees of flexion, forearm in neutral, wrist at 30 degrees of extension and no radioulnar deviation.[55] We then told them to squeeze the apparatus with their maximum strength for 6 seconds, without moving their wrist or forearm; they then had a one minute rest period.[56, 57] As has previously been done with Division 1 collegiate wrestlers, we required the athletes to perform three trials and the maximal value was used for analysis, which is among two accurate ways of measuring grip strength.[55, 58]

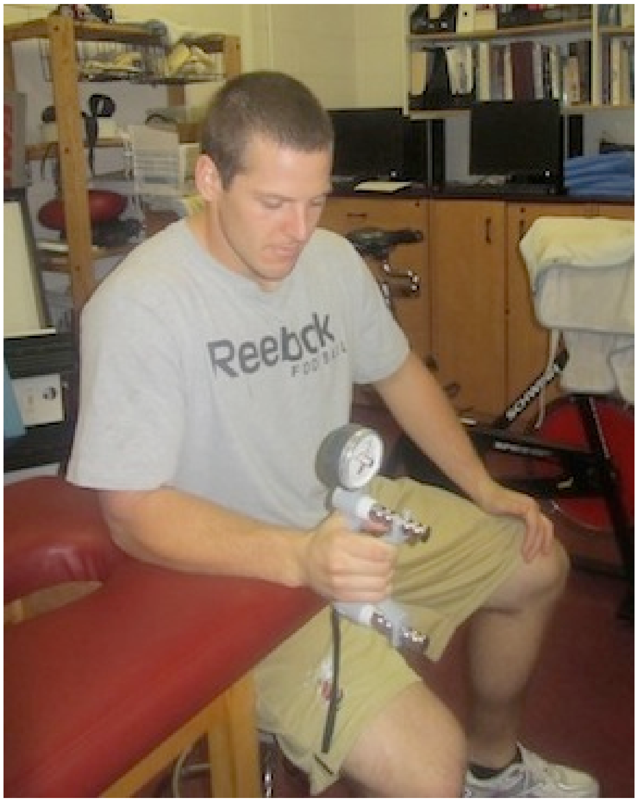

Figure 1. Participant completes handgrip strength test

We tested the participants' reaction time with the use of a 1.3 meter long stick attached to a rubber disk (see figure 2).[52] We asked the subject to sit down with his dominant forearm resting on a table and hand on the disk.[52] We randomly released the stick at predetermined intervals of 2 to 5 seconds for a total of 12 times; 2 practice trials and 10 test trials.[52] The subject was prompted to catch the stick as quickly as possible. The upper border of the subject's hand, where he caught the stick, was recorded for all 10 trials.[52] All 10 trials were averaged and converted to milliseconds, using $d=0.5gt^2$, which was then used for analysis.[52]

Figure 2. Participant completes reaction time test

We tested the participants' leg power via their vertical jump, using the Vertec vertical jump tester (Sports Imports, Hilliard, OH, USA) (see figure 3).[63] We explained to the subjects to stand with their dominant hand on the same side of the Vertex and perform three vertical jumps with a one minute rest period between each jump.[60] They were not allowed a preparatory step, but an arm swing was allowed.[60] We cued the subjects to jump and hit as many plastic vanes as possible; we counted and recorded the displaced vanes during the one minute rest.[60] The plastic vanes were then reset for each subsequent jump. We recorded all three heights and used the highest jump for analysis.[58, 60]

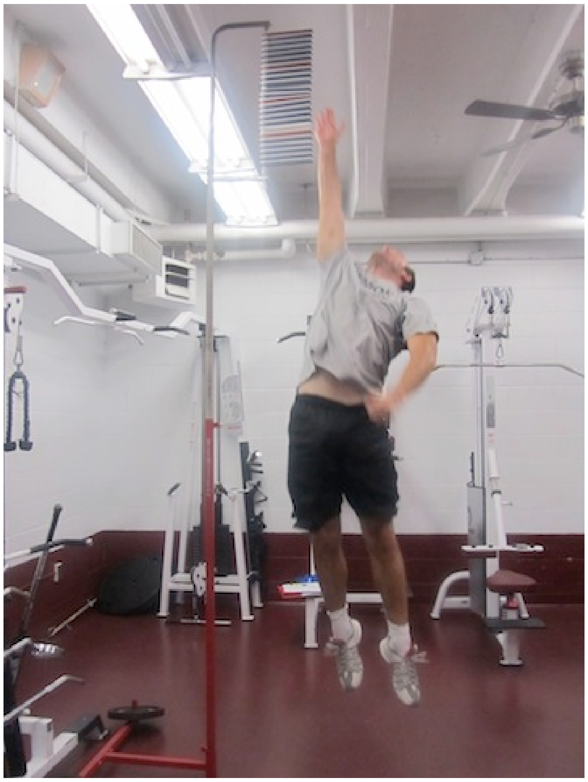

Figure 3. Participant completes vertical jump test

We measured the athletes' speed and agility through the use of the agility T-test on an indoor surface (see figure 4).[51] We asked subjects to warm-up prior to the completion of the test.[51] Prior to commencing the trial, we instructed the participants to start at the cone, run forward for 10 yards, touching the cone, shuffling left or right for 5 yards, touching the cone, shuffling 10 yards in the opposite direction, touching the cone, shuffling 5 yards back to and touching the middle cone, and running backwards for 10 yards through the starting cone.[51, 64] We allowed the participants to perform up to two submaximal trials prior to completing the test, if they necessitated.[64] The test was then completed three times, with a one minute rest period between each trial.[51] We recorded the three test times and the fastest time was kept for analysis.[51]

Figure 4. Cone placement for agility t-test

Procedures

Subjects were recruited for the study during summer team training. Every week, three to five athletes followed the 6-day protocol.

In the off-season, the athletes gathered on the Monday to complete paperwork and receive the AS and sleep diary. They wore the watch during the assigned 5-day period, filling out the sleep diary every night before going to bed and every morning upon awakening. On the 6th day they returned the AS and sleep journal and completed the battery of performance tests between 10:00am and 12:00pm, to mimic game day testing in-season (see figure 5).

During the in-season, the participants gathered on the Monday before the game to receive the AS and sleep diary. They followed the same procedure as in the off-season. On the 6th day, game day, the athletes returned the AS and sleep diary, warmed up and performed the battery of tests prior to the start of the game (see figure 6).

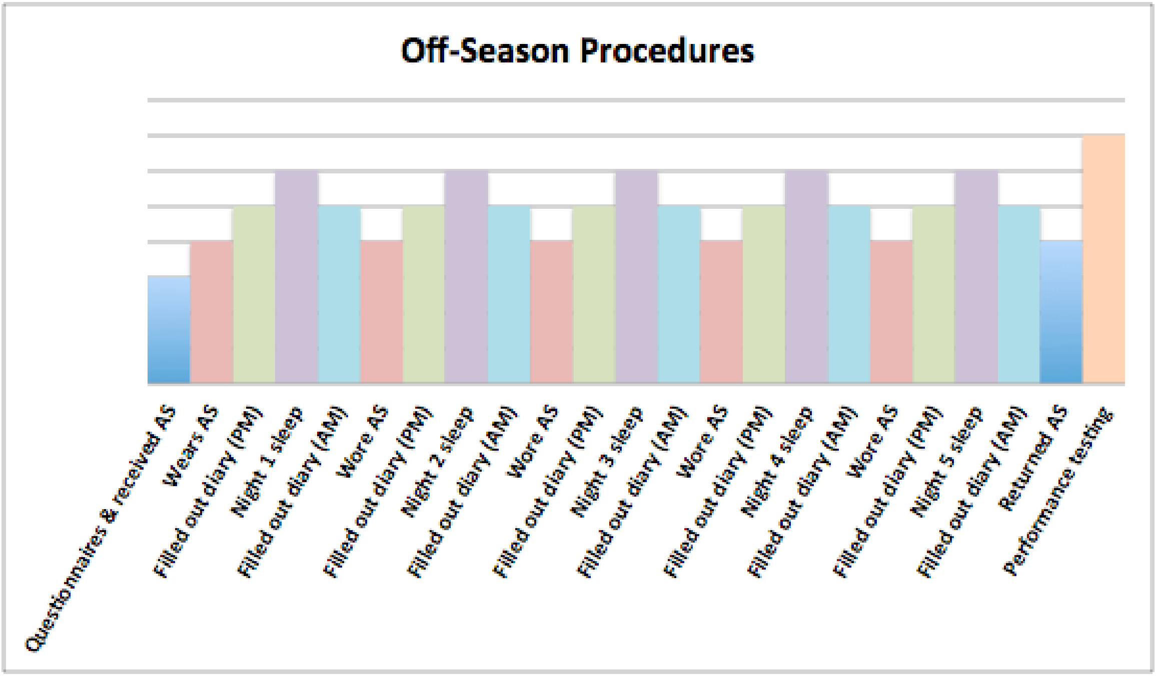

Figure 5. A schematic of the off-season procedures followed by the participants.

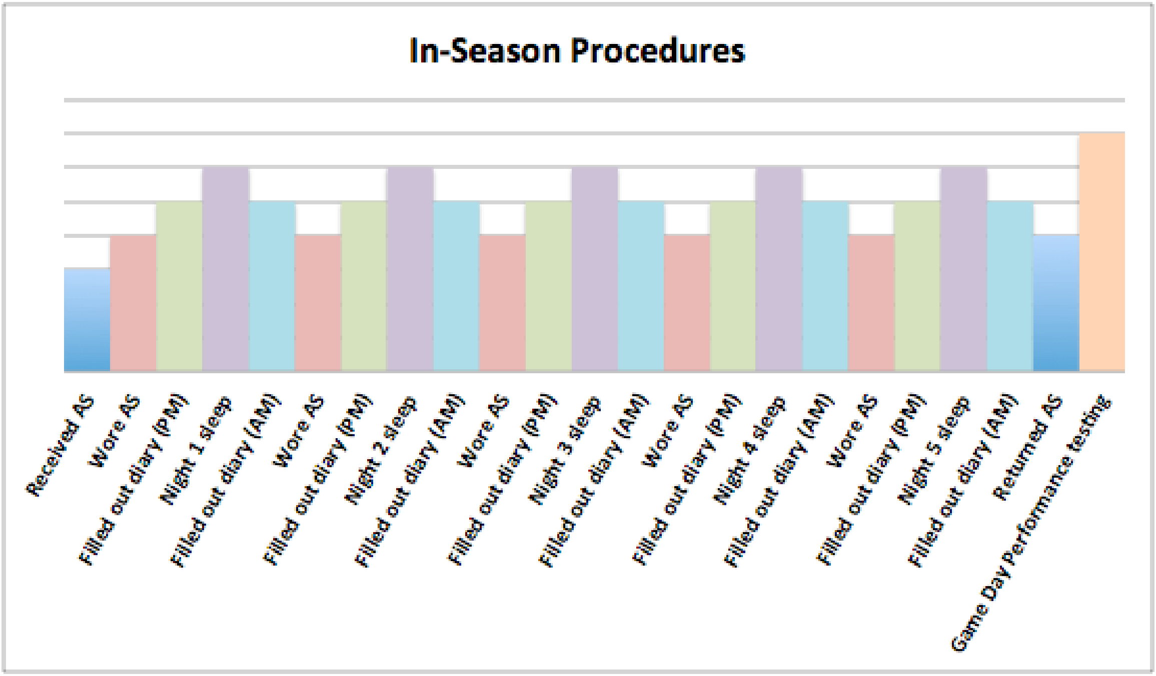

Figure 6. A schematic of the in-season procedures followed by the participants.

Statistical Analysis

Sleep data was collected during 5 nights during the off-season summer training and the 5 nights leading up to a regular season game. The sleep data included objective and subjective measures that were analyzed separately. At the end of each 5-day period, performance measures were recorded on the 6th day, therefore performance was compared from the off-season to the in-season.

All sleep measures were analyzed using a 2x5 ANOVA, comparing the 5 off-season nights to the 5 in-season nights. Both Season*Day and Season main effect were analyzed. Sleep measures that were compared between the two seasons include: objective TST, TBT, WASO and SE and subjective alertness, fatigue, mood, STAI-S, night pain, present pain, SQ, TST, SOL and WASO.

T-tests using the Bonferroni correction were used to compare off-season and in-season objective sleep measures on day 5, including, TST, TBT, WASO and SE. Moreover, t-tests were used to compare performance measures in- and off-season, which included: grip strength, vertical jump, agility t-test, and reaction time test.

Upon completing the sleep and performance analysis, additional comparisons and relationships were examined. We used Pearson correlations to examine the relationship between subjective and self-report sleep data and personal information respectively. Some of these additional measures can be seen in the results section and all other comparisons can be found in the appendix. These comparisons include: STAI-T with STAI-S; self-report fatigue with PSQI, ESS, STAI-T and STAI-S; self-report alertness with PSQI, STAI-T and STAI-S; and self-report sleep quality with STAI-T and STAI-S.

All data were analyzed using the Statistical Package for the Social Sciences (SPSS 19.0 for Windows, SPSS Inc., Chicago, IL).

RESULTS

Objective measures

There was no significant change in most of the sleep parameters between the off-season and in-season. There was no significant changes in objective sleep measures of TST (F(4,36)=0.92, p=0.463) , TBT (F(4,36)=0.58, p=0.677), WASO (F(4,36)=0.35, p=0.838), and SE (F(4,36)=0.51, p=0.722) (see figures 7-10). When analyzing the season main effects, there was a trend towards an increase in TST and TBT, while there was no significant change in WASO and SE (see table 1). When comparing these measures on day 5 in and out of season, no significant change was seen either (p values ranging from 0.227 to 0.885, see table 2).

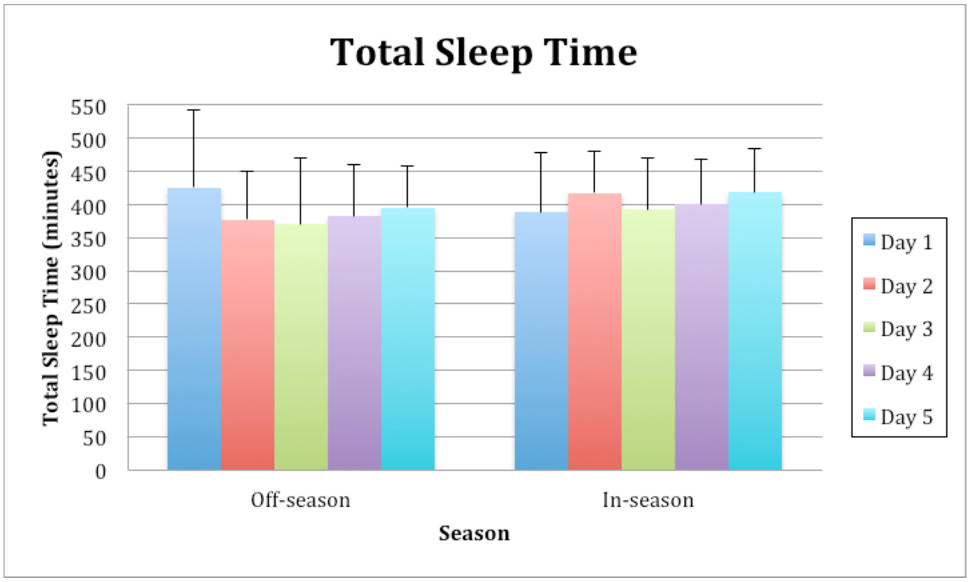

Figure 7. Objective TST off- and in-season shows no significant change

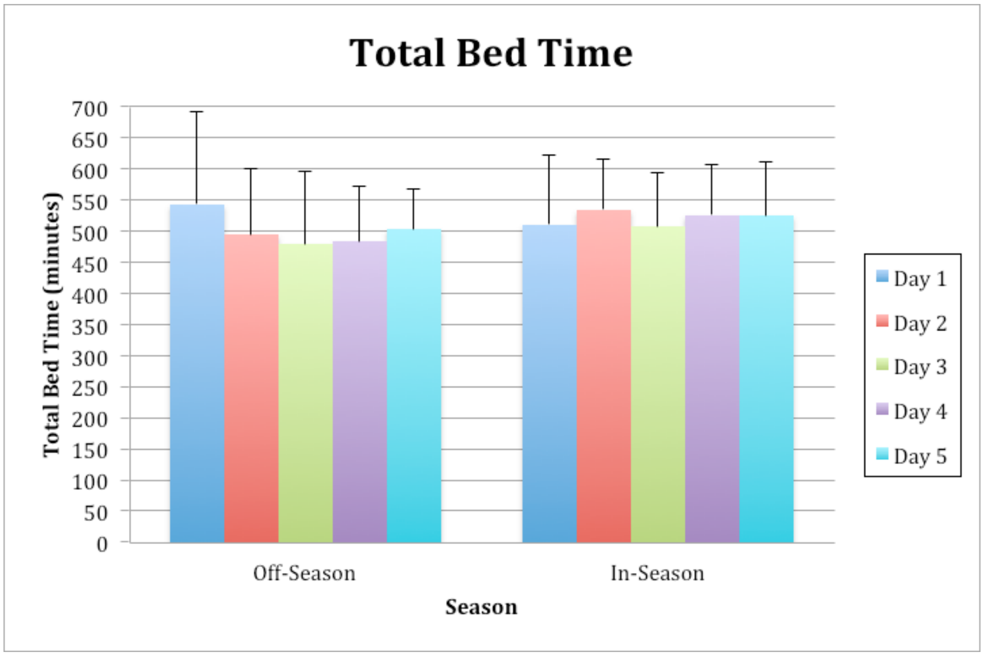

Figure 8. Objective TBT off- and in-season shows no significant change

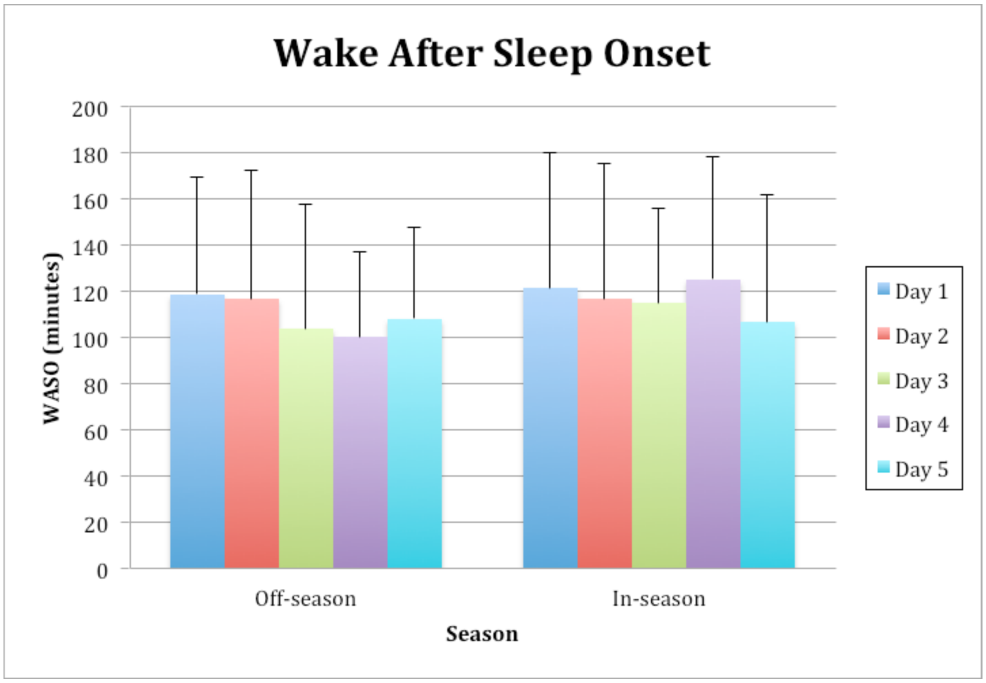

Figure 9. Objective WASO off- and in-season shows no significant change

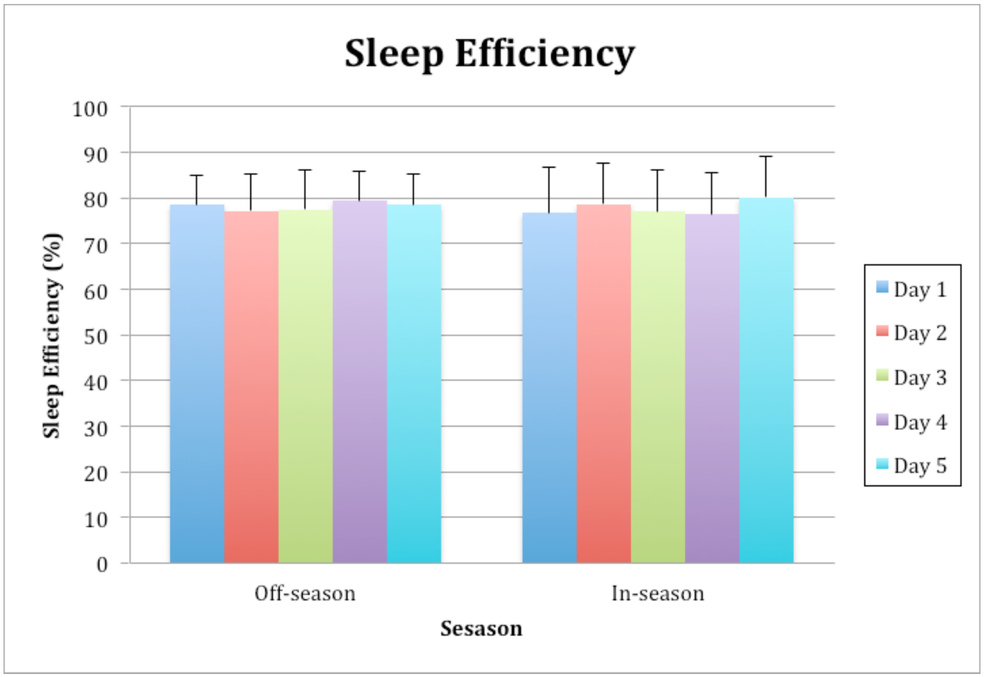

Figure 10. Objective SE off- and in-season shows no significant change

Table 1. Objective sleep measures Season Main Effects				
Sleep measure	**Off-season**	**In-season**	**F (1,9)**	**p**
TST	375.2±70.2 min	409.3±72.4min	4.79	0.056
TBT	486.1±90.6min	531.2±96.8min	4.88	0.054
WASO	110.8±47.6min	121.9±51.4min	0.84	0.382
SE	77.6±7.2%	77.5±7.9%	0.00	0.962

Table 1. A trend towards an increase in season main effects TST and TBT (*p*=0.054 and 0.056), but no change in WASO and SE (*p*=0.382 and 0.962)

Table 2. Day 5 in and out of season Objective Sleep Measures				
Sleep Measure	**Off-season**	**In-season**	**t(23)**	***Sig (2-tailed)**
TST	394.2±62.3min	418.6±65.2min	-1.24	0.227
TBT	502.8±65.0min	525.3±85.5min	-1.15	0.260
WASO	108.2±39.3min	106.7±54.9min	-1.15	0.885
SE	78.5±6.6%	80.1±8.7%	-0.83	0.413
**Sig. <0.05*				

Table 2. No change in day 5 objective sleep measures between the off-season and in-season (*p* values ranging from 0.227 to 0.885)

Subjective measures

There was no significant change in all subjective sleep measures, except for night pain and present pain in and out of season. Upon awakening, there was no significant change in alertness (F(4,92)=1.550, p=0.194), fatigue (F(4,92)=1.039, p=0.392), mood (F(4,92)=1.014, p=0.405) and anxiety levels based on the STAI-S (F(4,92)=1.657, p=0.167) (see figures 11-14). There was a significant change in perceived night pain in and out of season (F(4,92)=4.676, p=0.002) and in present pain in and out of season (F(4,92)=4.843, p=0.001) (see figures 15-16). In and out of season subjective sleep measures presented no significant changes; SQ (F(4,92)=0.067, p=0.992), TST (F(4,92)=0.385, p=0.819), SOL (F(4,92)=1.018, p=0.403), and WASO (F(4,92)=0.406, p=0.804) (see figures 17-20). When analyzing the season main effects, there were no significant changes in any subjective variables (see table 3).

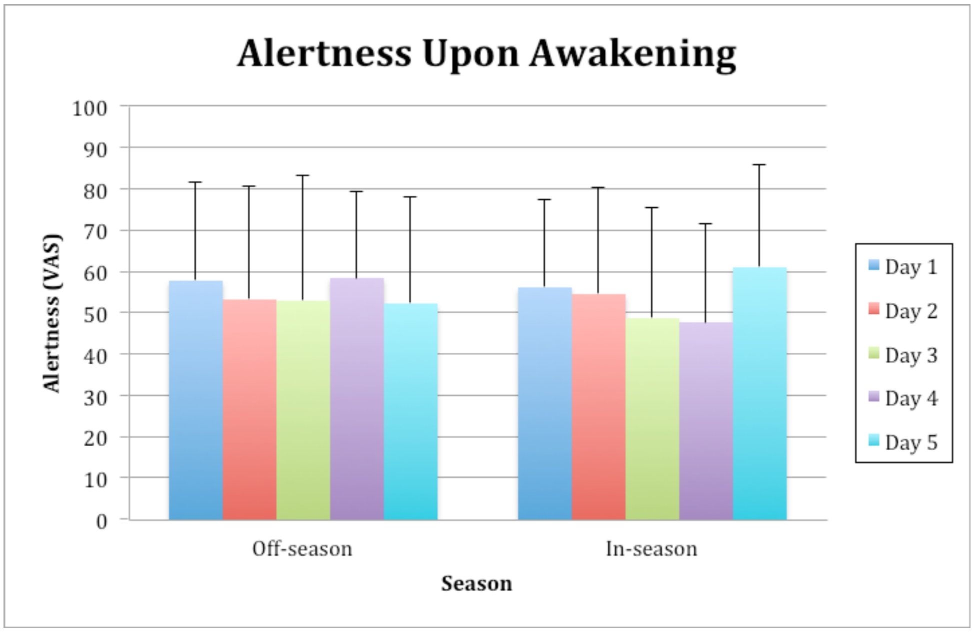

Figure 11. No significant change in alertness between off- and in-season

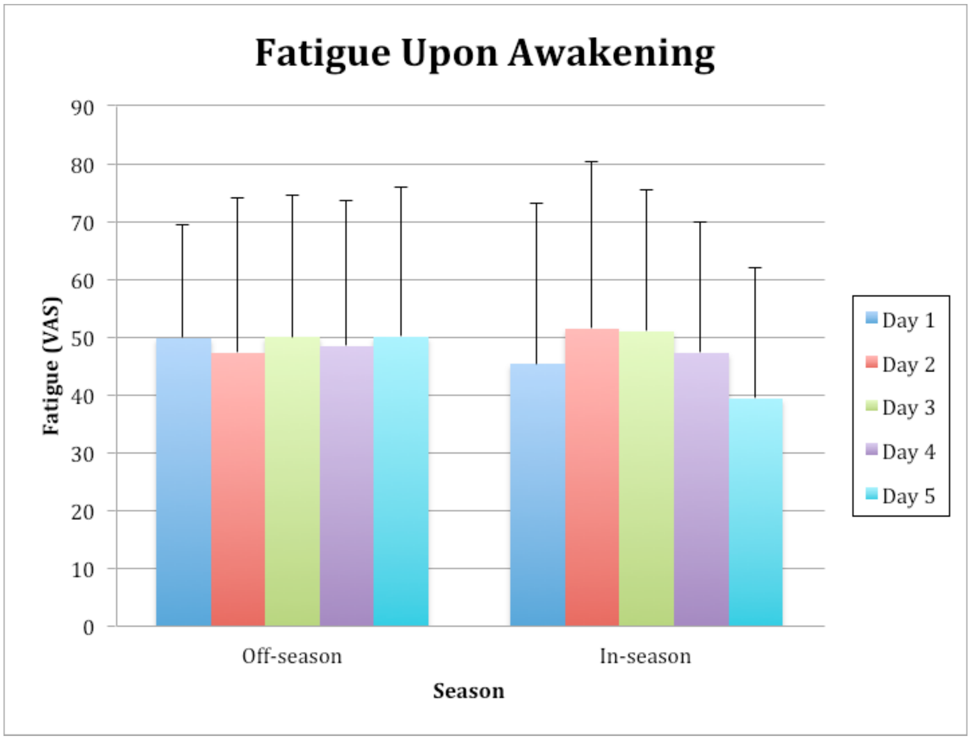

Figure 12. No significant change in morning fatigue between off- and in-season

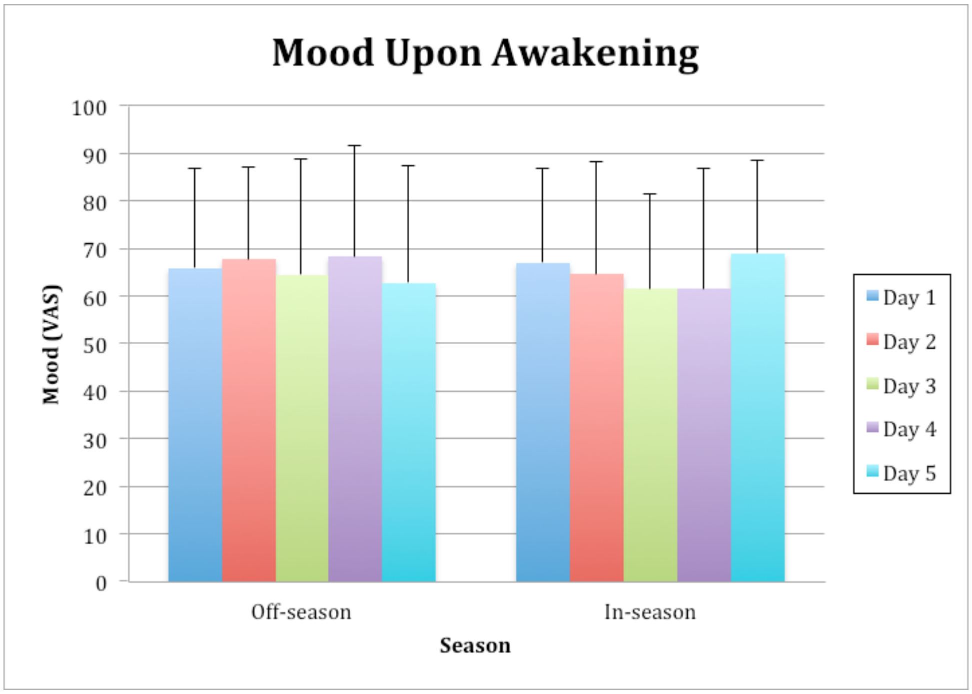

Figure 13. No significant change in off- and in-season mood.

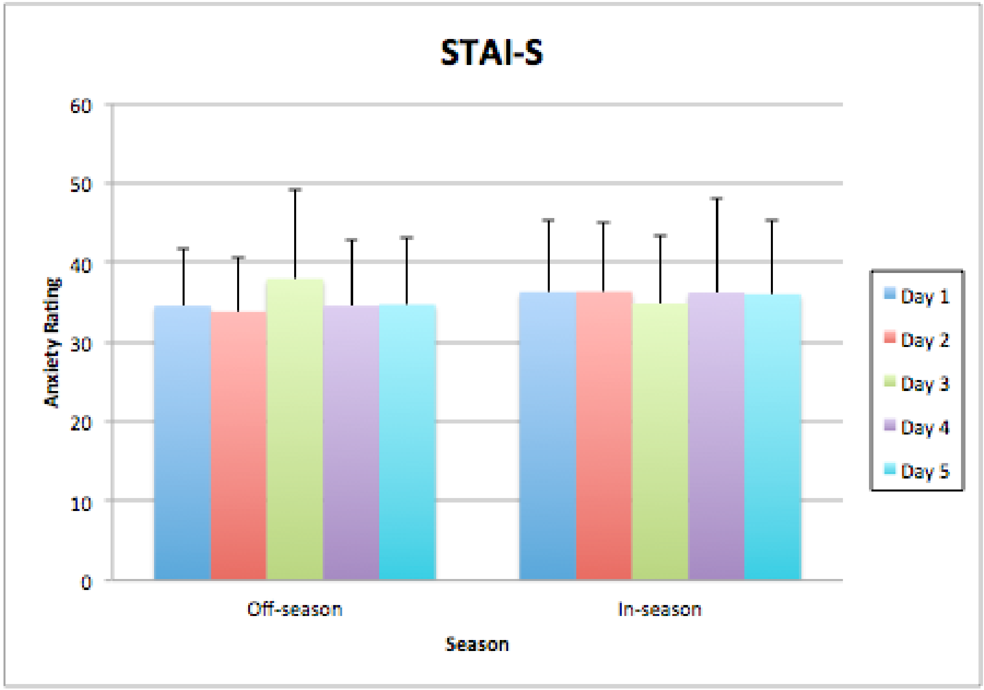

Figure 14. No significant change in anxiety state between off- and in-season

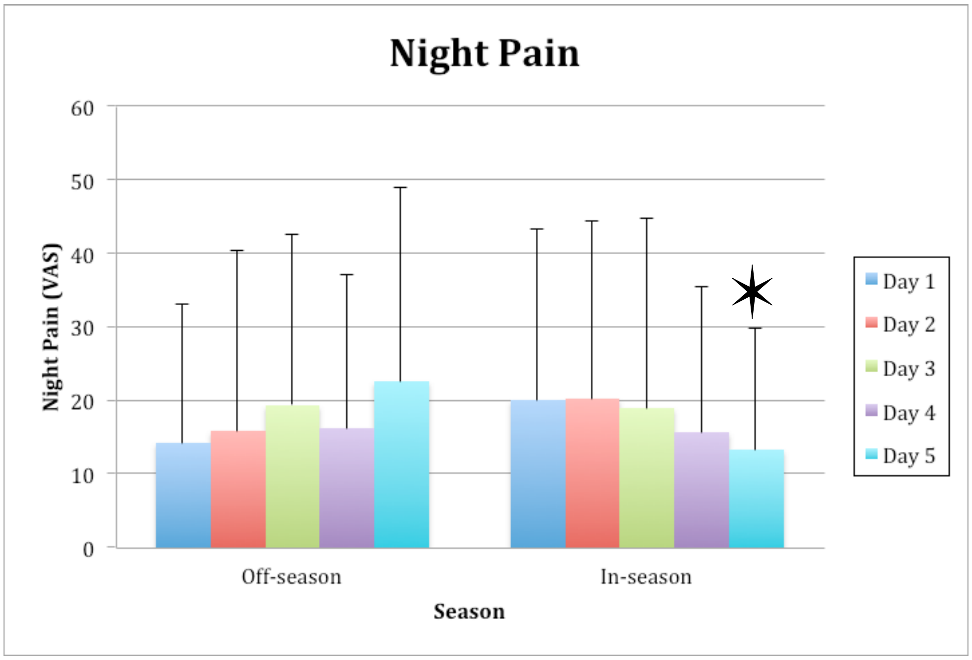

Figure 15. Significantly less night pain on day 5 in-season versus off-season (*p*=0.002)

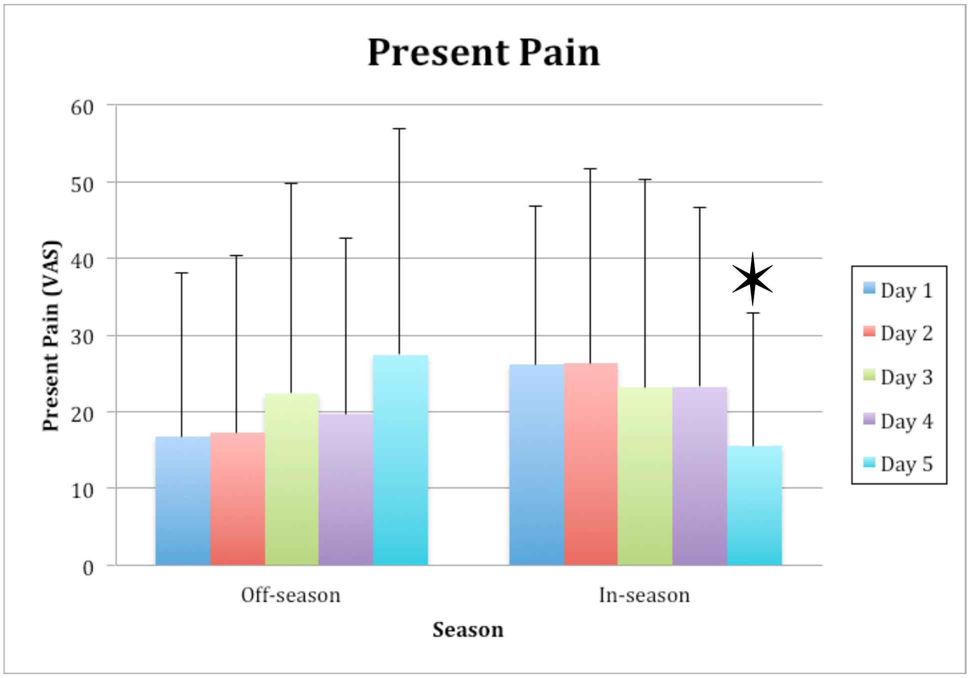

Figure 16. Significantly less present pain on day 5 in-season versus off-season (*p*=0.001)

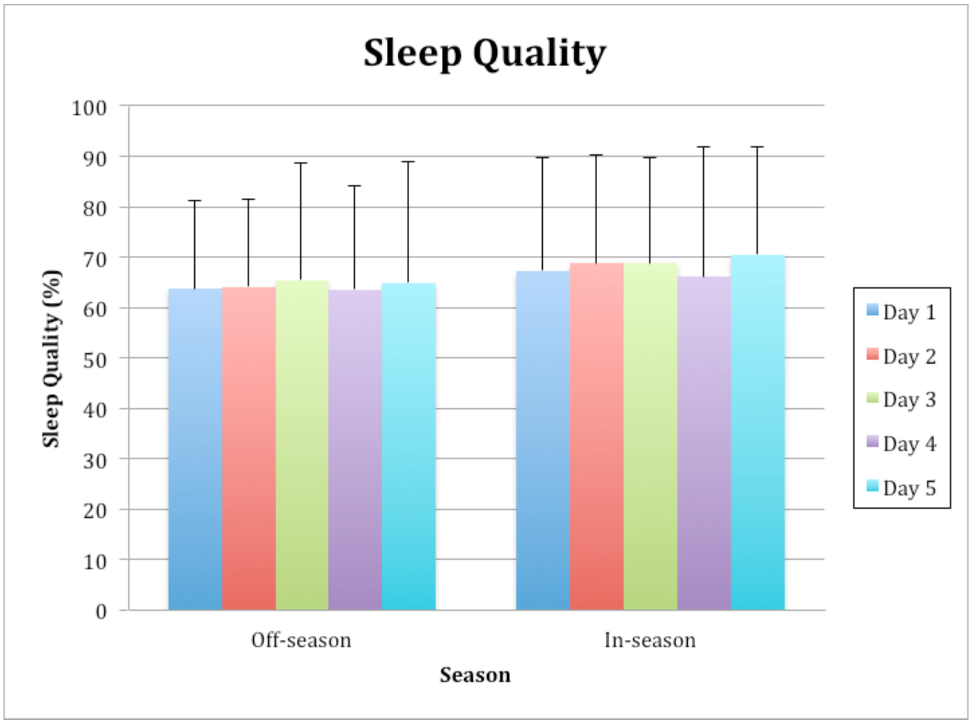

Figure 17. No significant change in SQ between seasons

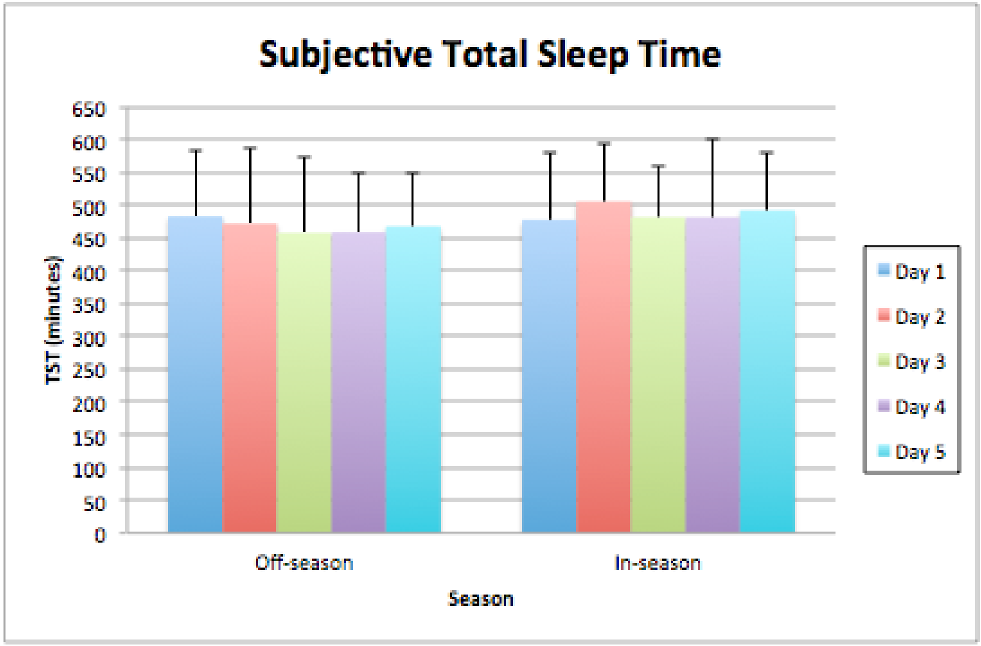

Figure 18. No significant change in subjective TST between seasons

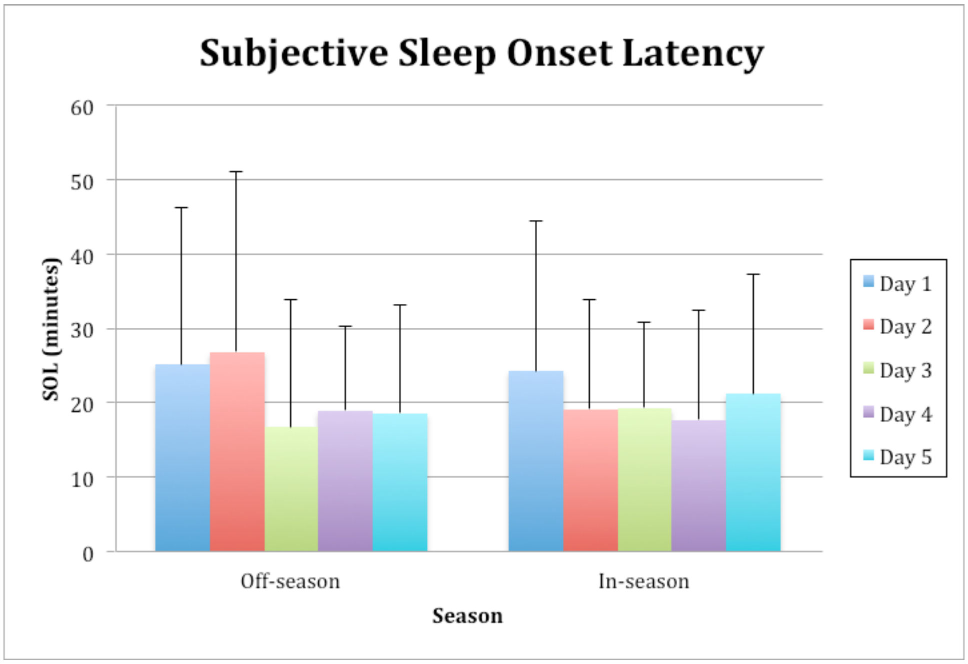

Figure 19. No significant change in subjective SOL between seasons

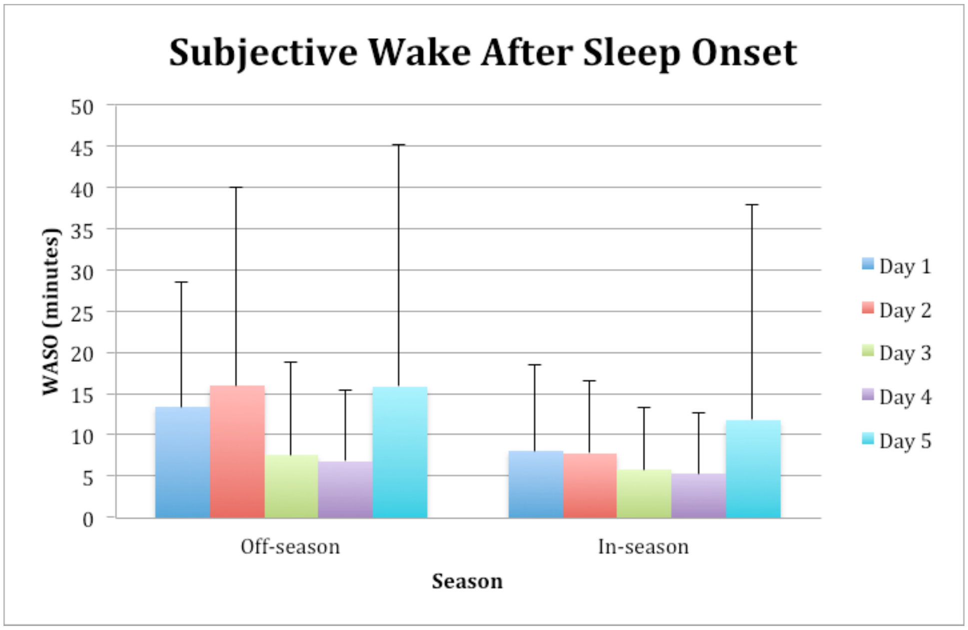

Figure 20. No significant change in subjective WASO between seasons

Table 3. Subjective sleep measures Season Main Effects				
Sleep measure	**Off-season**	**In-season**	**F(1,23)**	**p**
Alertness	54.9±25.3mm	53.5±24.5mm	0.46	0.503
Fatigue	49.1±24.0mm	46.8±25.8mm	0.42	0.523
Mood	65.8±22.2mm	64.6±21.5mm	0.15	0.700
STAI-S	35.1±8.4	35.9±9.3	0.40	0.529
Night Pain	17.5±22.7mm	17.5±21.9mm	0.00	0.997
Present Pain	20.7±24.9mm	22.8±22.9mm	0.31	0.578
SQ	64.2±20.3mm	68.2±22.0mm	2.57	0.122
TST	468.0±99.9min	487.4±95.6min	1.86	0.185
SOL	21.2±18.3min	20.3±15.5min	0.14	0.706
WASO	11.9±19.3min	7.7±13.8min	2.04	0.166

Table 3. No significant change in season main effects of subjective sleep measures

Performance measures

There were no significant changes in performance measures in and out of season (see table 4). The reason in which the standard deviation differs between performance tests is due to the fact that some athletes did not want to perform lower body testing on game day, as they feared aggravating previous, lingering lower body injuries.

Table 4. Performance measures in and out of season

Performance test	Off-season	In-season	t	df	*Sig (2-tailed)
Agility t-test	9.4±0.9 sec	9.3±0.8 sec	-0.78	18	0.441
Handgrip test	61.1±10.9 kg	63.5±13.3 kg	-0.73	23	0.470
Reaction time test	187.2±28.5 ms	180.5±26.8 ms	1.35	23	0.190
Vertical jump	65.6±12.2 cm	67.4±9.8 cm	-0.16	19	0.872
**Sig. <0.05*					

Table 4. No significant difference in performance test results for off-season and in-season.

Subjects' sleep and health information

In previous studies, poor sleep hygiene and daytime sleepiness are used as exclusion criteria, but were not in this study.[36, 68] Our purpose was to measure sleep and performance in athletes regardless of their self-reported sleepiness and anxiety. In most cases, the results of the proceeding questionnaires on sleepiness and anxiety are used as diagnostic tools to separate healthy and normal sleepers from those with medical problems or sleep disorders; a study looking at sleep quality in chronic pain sufferers used the PSQI and BDI-II results as exclusion criteria and a study used the morningness-eveningness questionnaire to select participants for their study looking at the effects of sleep deprivation on anaerobic performance.[18, 20-25, 36, 68-70] These questionnaires were not used as exclusion criteria in our project as our goal was to have a good representation of the sleep parameters of the veterans and/or starters of the football team as a whole, and not just those who presented normal-range results on the questionnaires.

All subjects were healthy with SF-12 scores of 53.13±5.31 for the physical component and 53.22±7.55 for the mental component.[21, 22] Based on questionnaires, their sleep hygiene was below normal; their average PSQI score was 5.9±3.0, ranging from 1 to 12, surpassing the cut-off of 5 for good sleep quality.[20] Their daytime sleepiness based on the ESS was also relatively high, averaging 7.9±3.7, ranging from 0 to 13, where 9 is the upper limit for having average daytime sleepiness.[18] The BDI-II was used to investigate the participants' level of depression; averaging 5.3±3.8, which is less than 9, showing no clinical concerns for depression.[23] Seasonality was also measured using the SPAQ; no participants suffered from the effects of change in season.[24, 25] As for chronotypes, 67% of the participants were neither morning or evening type, 4% were moderate morning type and definite evening type, and 25% were moderate evening type.[69] Last, trait anxiety levels, STAI-T, averaged 34.9±7.1, corresponding to the medium level of anxiety range of 34 to 46 and state anxiety levels, STAI-S, averaged 35.1±8.4 in the off-season and 35.9±9.3 in the in-season, also corresponding to the medium level of anxiety range of 31 to 43.[70]

Additionally, the bedtimes of all 5 nights in and out of season were recorded (see table 5).

Table 5. Off-Season and In-Season Bedtimes

	Off-Season Bedtime	**Range**	**In-Season Bedtime**	**Range**
Day 1	12:37:45am	10:30pm - 3:30am	1:03:48am	10:20pm - 5:30am
Day 2	1:02:42am	11:00pm - 6:00am	1:01:00am	11:00pm - 3:45am
Day 3	1:14:18am	8:00pm - 6:00am	12:39:28am	11:00pm - 4:00am
Day 4	1:03:45am	10:30pm - 6:00am	1:04:40am	10:30pm - 6:00am
Day 5	12:46:47am	10:00pm - 2:30am	12:19:25am	10:00pm - 3:30am

Table 5. Recorded average bedtimes and ranges during the off-season and in-season.

Relationship between sleep and health information and subjective sleep measures

There was a positive correlation between anxiety trait, STAI-T (M=34.91 SD=7.12), and average anxiety state in-season, STAI-S (M=35.93 SD=9.39),*r*=0.637*, p*=0.001*, n*=24 (see figure 21)*;* and day on the 5th day in-season (M=36 SD=9.31), *r*=0.569, *p*=0.004, *n*=24 (see figure 22).

Self-reported fatigue was correlated to the PSQI, ESS, STAI-T and STAI-S. On day 5 in-season, there was a trend towards a positive correlation between fatigue (M=39.37 SD=25.80) and PSQI (M=5.95 SD=3.05), *r*=0.401, *p*=0.052, *n*=24 (see figure 23). Anxiety trait, STAI-T (M=34.91 SD=7.12), was positively correlated to the average in-season fatigue (M=46.86 SD=25.86), *r*=0.454, *p*=0.026, *n*=24 (see figure 24); and day 5 in-season fatigue (M=39.37 SD=25.80), *r*=0.463, *p*=0.023, *n*=24 (see figure 25). Moreover, anxiety state was positively correlated to fatigue; average in-season STAI-S (M=35.93 SD=9.39) was positively correlated to average in-season fatigue (M=46.86 SD=25.86), *r*=0.523, *p*=0.009, *n*=24 (see figure 26); and day 5 in-season STAI-S (M=36 SD=9.31) was positively correlated to day 5 in-season fatigue (M=39.37 SD=25.80), *r*=0.462, *p*=0.023, *n*=24 (see figure 27).

Self-report alertness upon awakening was negatively correlated to the PSQI, STAI-T and STAI-S. There was a negative correlation between PSQI (M=5.95 SD=3.05) and average in-season alertness (M=53.57 SD=24.50), *r*=-0.486, *p*=0.016, *n*=24 (see figure 28); and day 5 in-season alertness (M=61.08 SD=24.66), *r*=-0.442, *p*=0.031, *n*=24 (see figure 29). STAI-T (M=34.91 SD=7.12) was also negatively correlated to average in-season alertness (M=53.57

SD=24.50), *r*=-0.450, *p*=0.028, *n*=24 (see figure 30) and to day 5 in-season alertness (M=61.08 SD=24.66), *r*=-0.508, *p*=0.011, *n*=24 (see figure 31). Average off-season anxiety state, STAI-S (M=35.10 SD=8.45), was negatively correlated to average off-season alertness (M=54.95 SD=25.34), *r*=-0.603, *p*=0.002, *n*=24 (see figure 32); average in-season STAI-S (M=35.93 SD=9.39) was also negatively correlated to average in-season alertness (M=53.57 SD=24.50), *r*=-0.416, *p*=0.043, *n*=24 (see figure 33).

Lastly, subjective sleep quality was negatively correlated to anxiety trait and state. STAI-T (M=34.91 SD=7.12) was negatively correlated to average off-season sleep quality (M=64.21 SD=20.33), *r*=-0.427, *p*=0.038, *n*=24 (see figure 34); average in-season sleep quality (M=68.28 SD=22.03), *r*=-0.511, *p*=0.011, *n*=24 (see figure 35); and day 5 in-season sleep quality (M=70.42 SD=21.24), *r*=-0.557, *p*=0.005, *n*=24 (see figure 36). Average off-season STAI-S (M=35.10 SD=8.45) was negatively correlated to average off-season sleep quality (M=64.21 SD=20.33), *r*=-0.614, *p*=0.001, *n*=24 (see figure 37). Average in-season STAI-S (M=35.93 SD=9.39) was negatively correlated to average in-season sleep quality (M=68.28 SD=22.03), *r*=-0.470, *p*=0.020, *n*=24 (see figure 38).

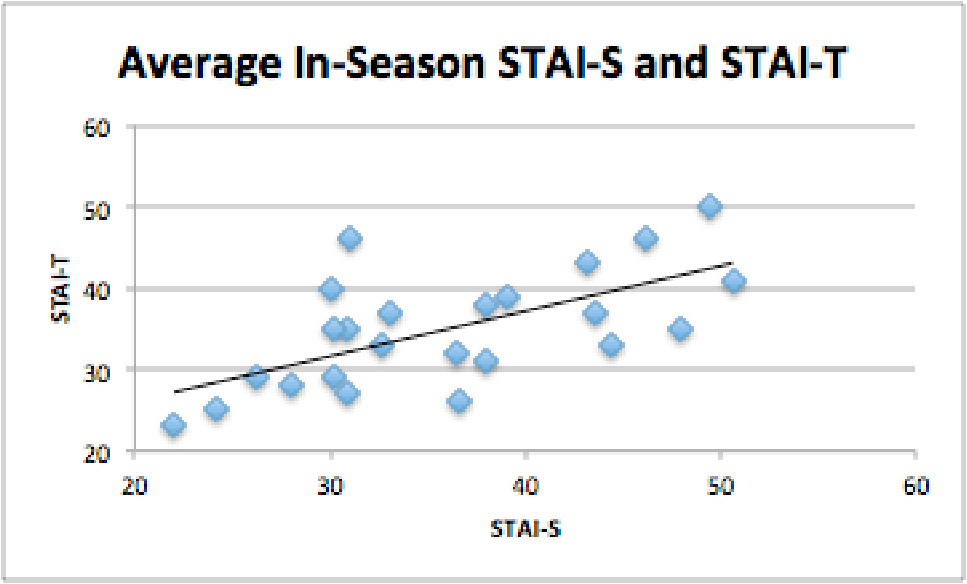

Figure 21. Positive correlation between average in-season anxiety state and anxiety trait

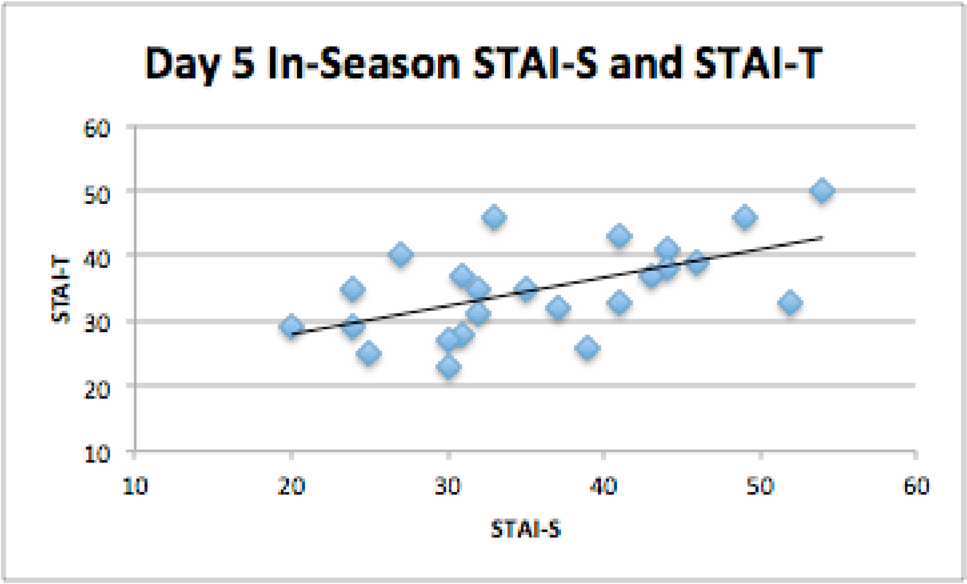

Figure 22. Positive correlation between day 5 in-season anxiety state and anxiety trait.

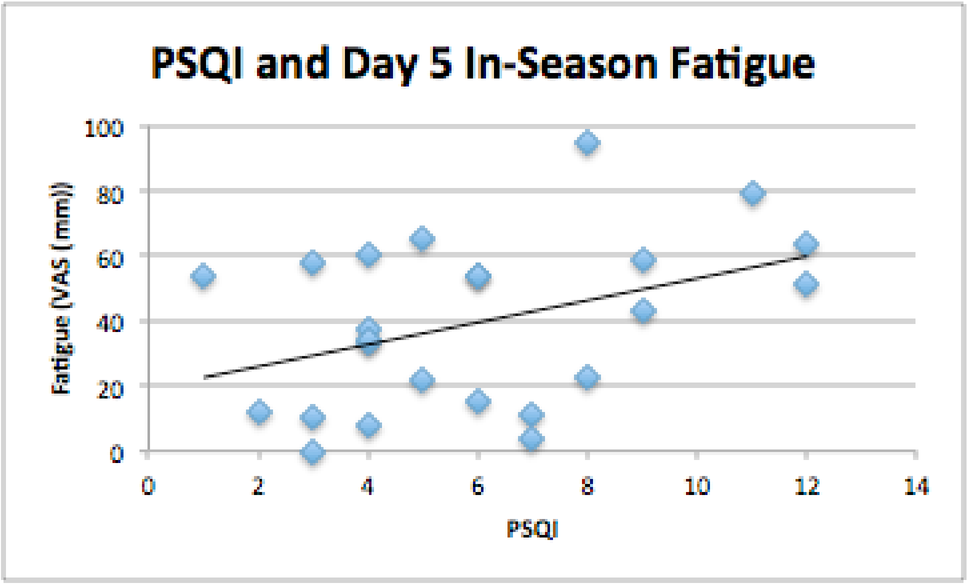

Figure 23. Positive correlation between day 5 in-season fatigue and subjective sleep hygiene, based on PSQI

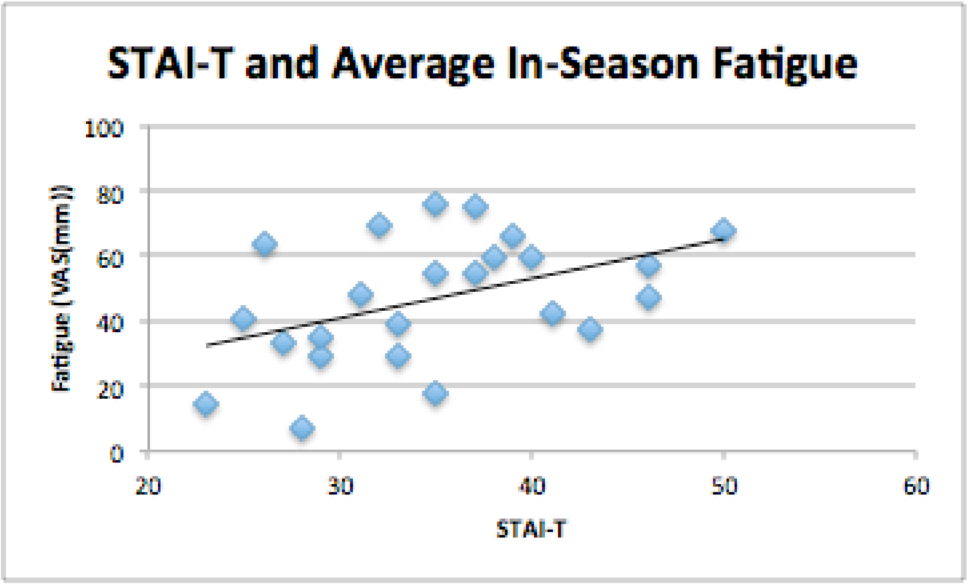

Figure 24. Positive correlation between anxiety trait and average in-season fatigue

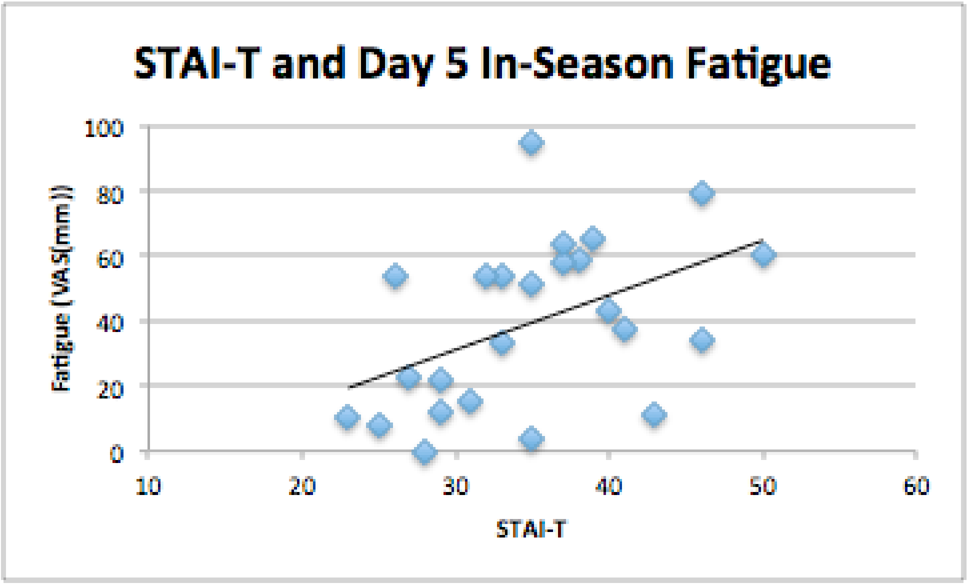

Figure 25. Positive correlation between anxiety trait and day 5 in-season fatigue

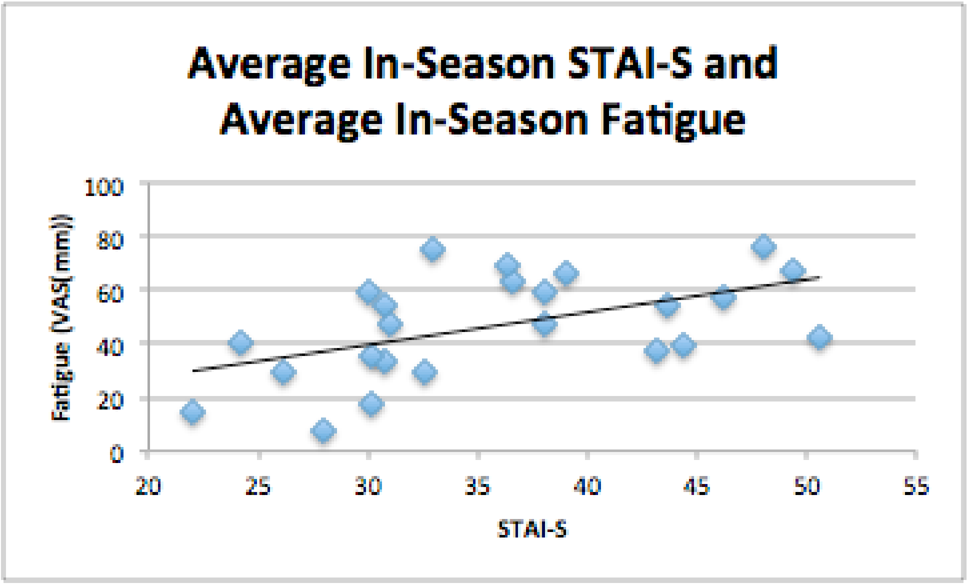

Figure 26. Positive correlation between average in-season anxiety state and fatigue

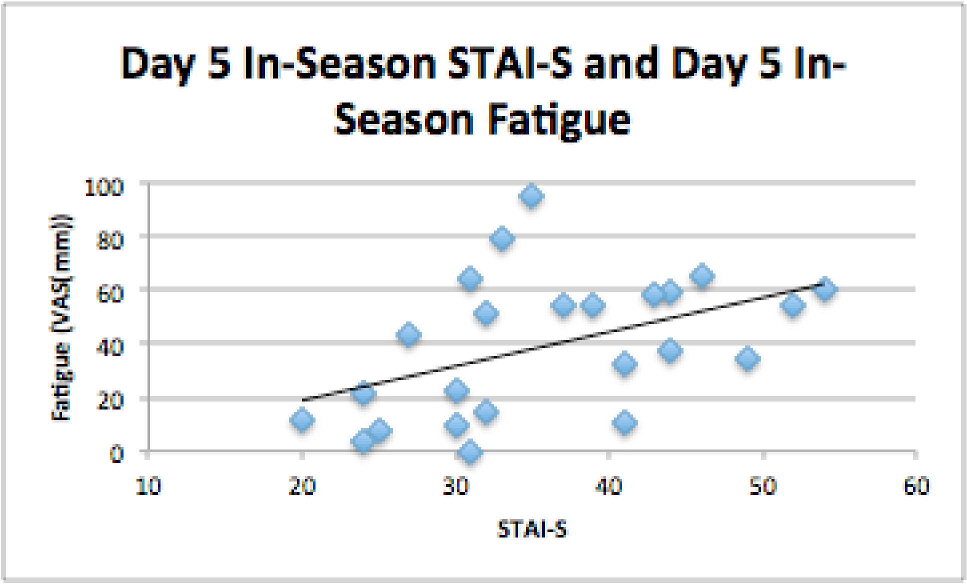

Figure 27. Positive correlation between day 5 in-season anxiety state and fatigue

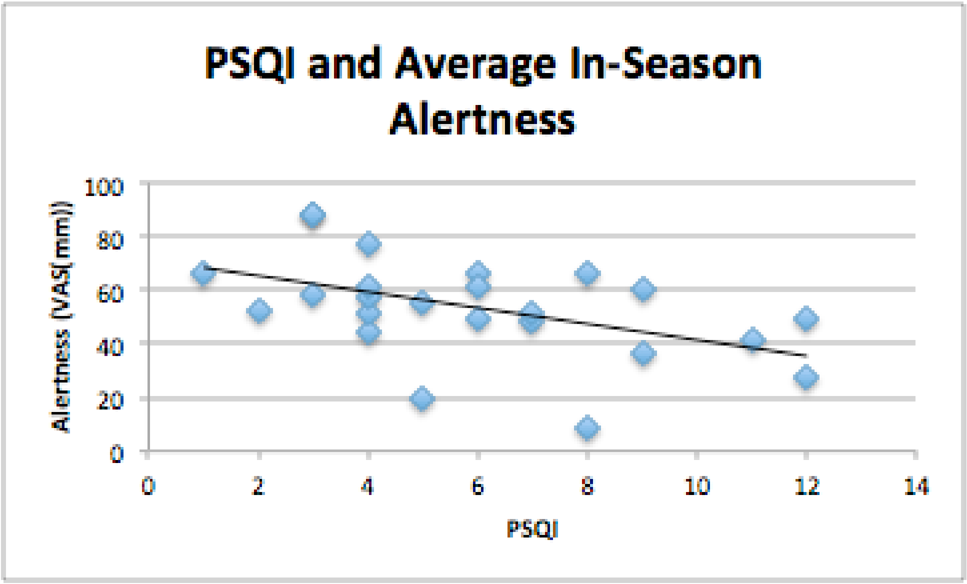

Figure 28. Negative correlation between subjective sleep hygiene and average in-season alertness upon awakening

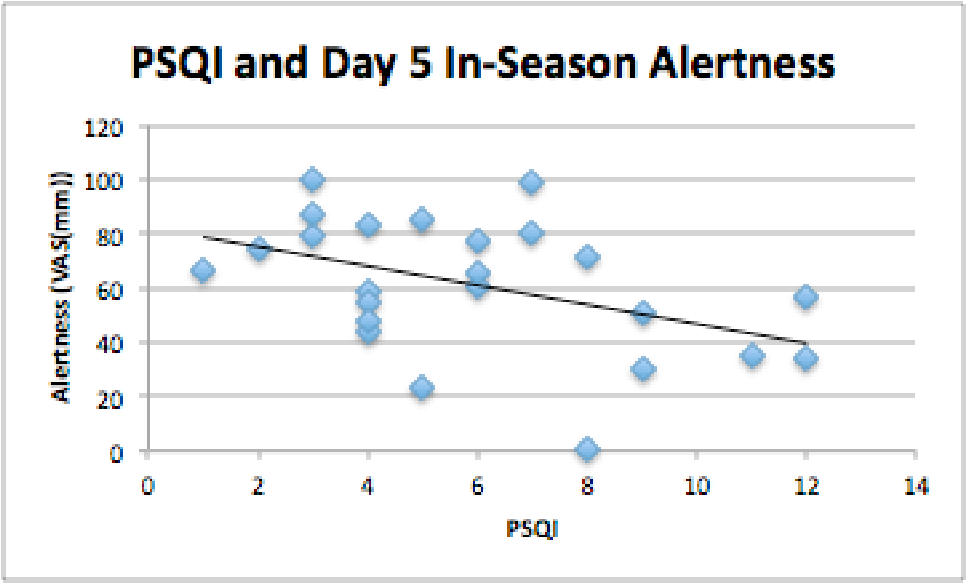

Figure 29. Negative correlation between subjective sleep hygiene and day 5 in-season alertness upon awakening

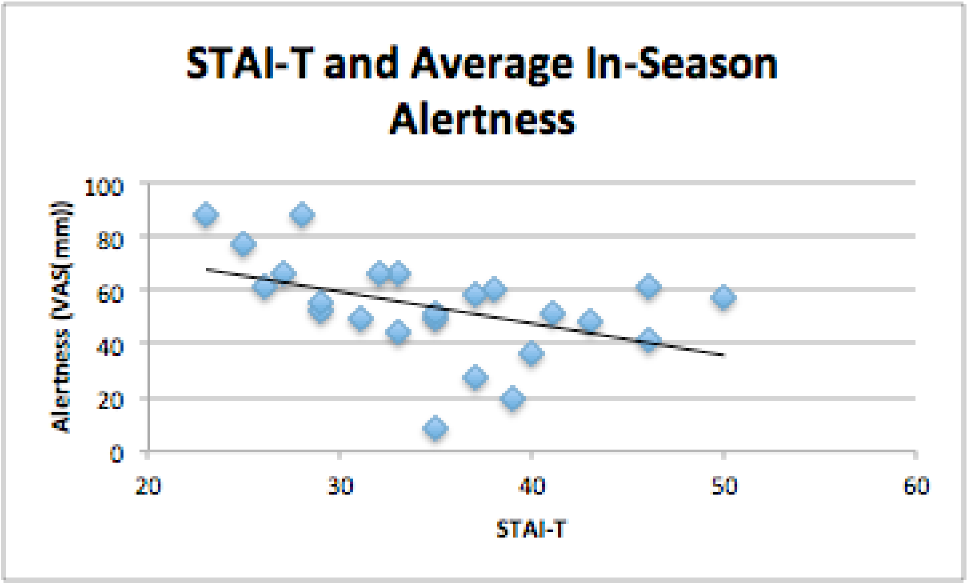

Figure 30. Negative correlation between anxiety trait and average in-season alertness upon awakening

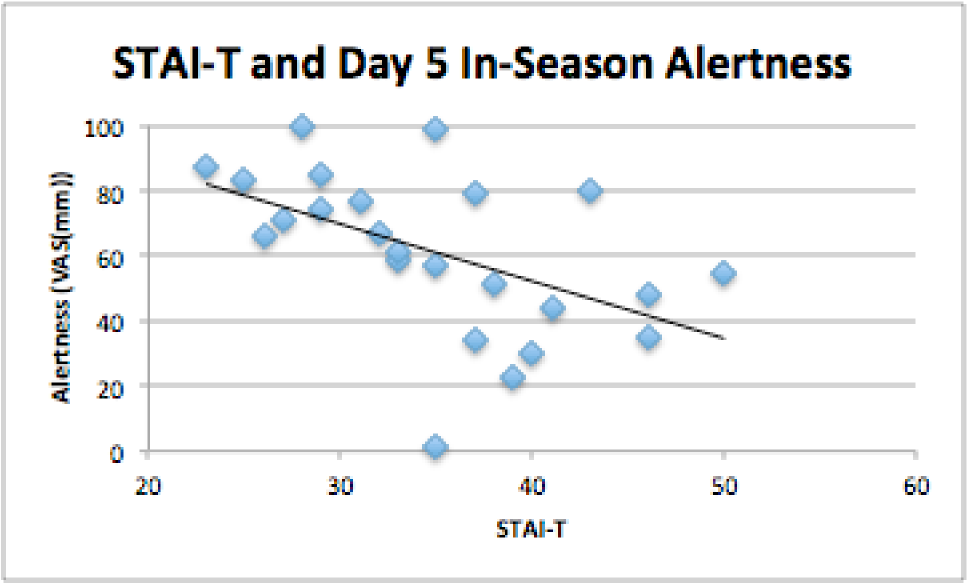

Figure 31. Negative correlation between anxiety trait and day 5 in-season alertness upon awakening

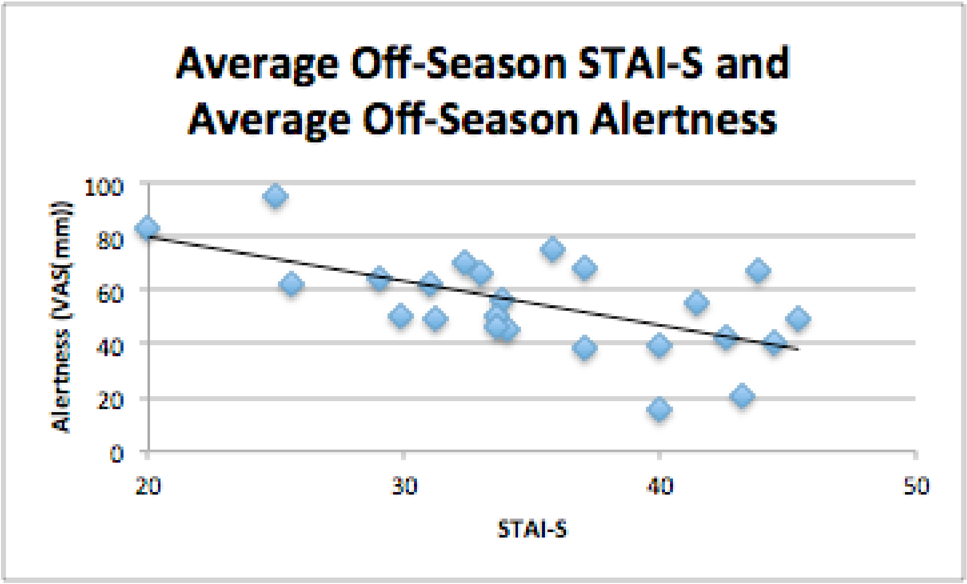

Figure 32. Negative correlation between average off-season anxiety state and alertness upon awakening

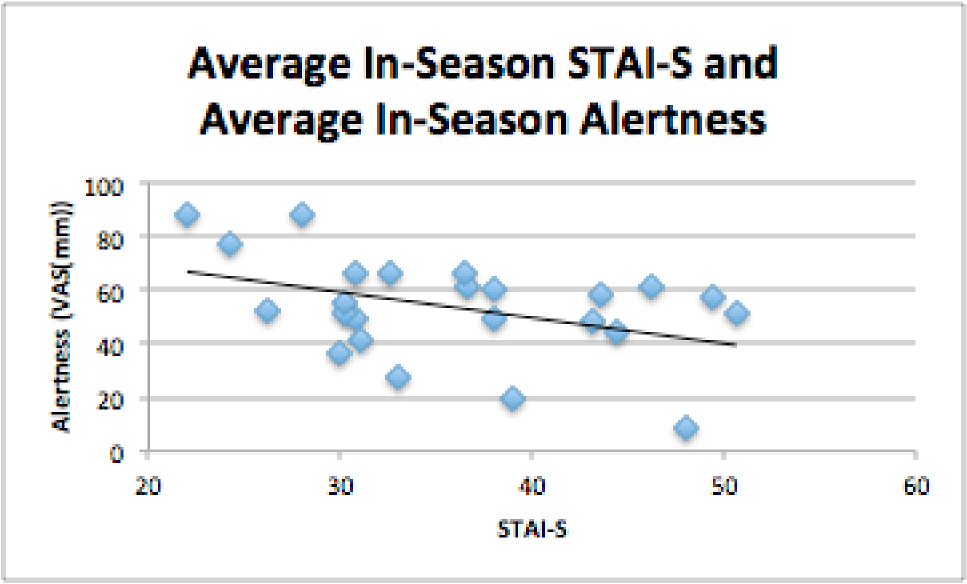

Figure 33. Negative correlation between average in-season anxiety state and alertness upon awakening

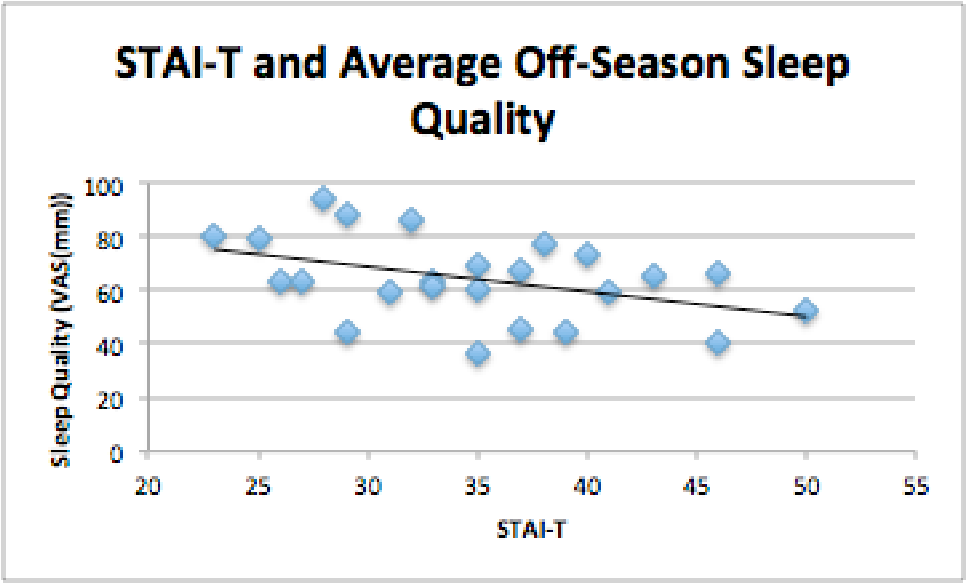

Figure 34. Negative correlation between anxiety trait and average off-season sleep quality

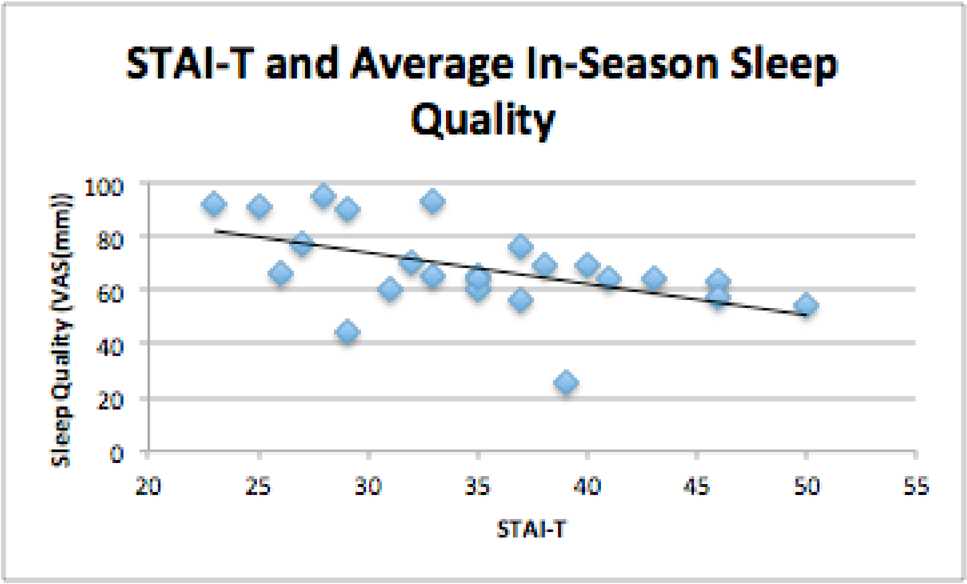

Figure 35. Negative correlation between anxiety trait and average in-season sleep quality

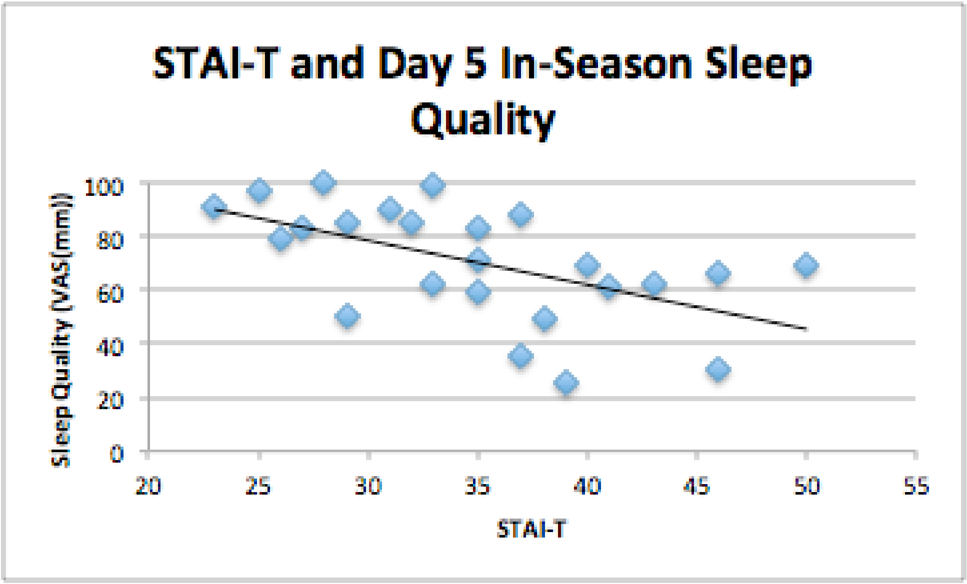

Figure 36. Negative correlation between anxiety trait and day 5 in-season sleep quality

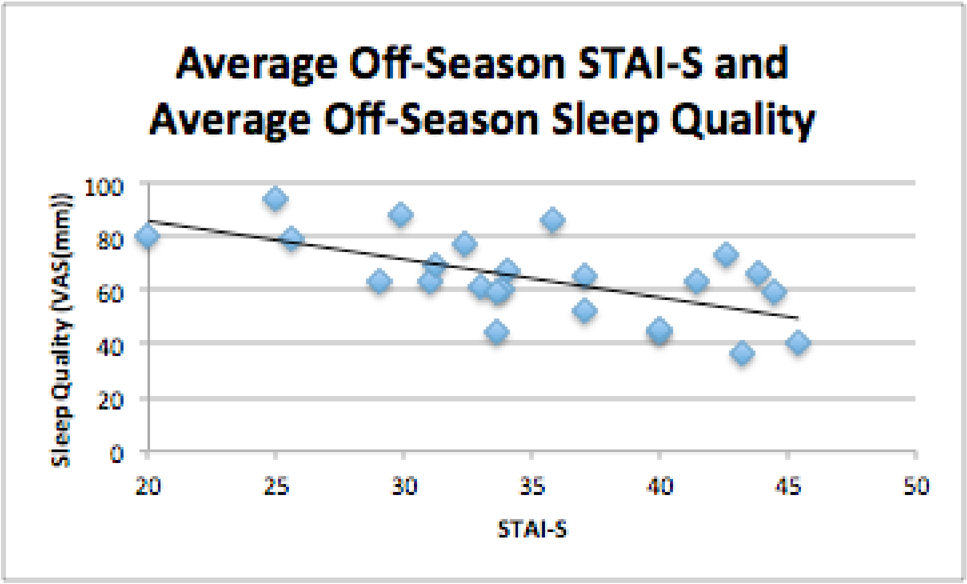

Figure 37. Negative correlation between average off-season anxiety state and sleep quality

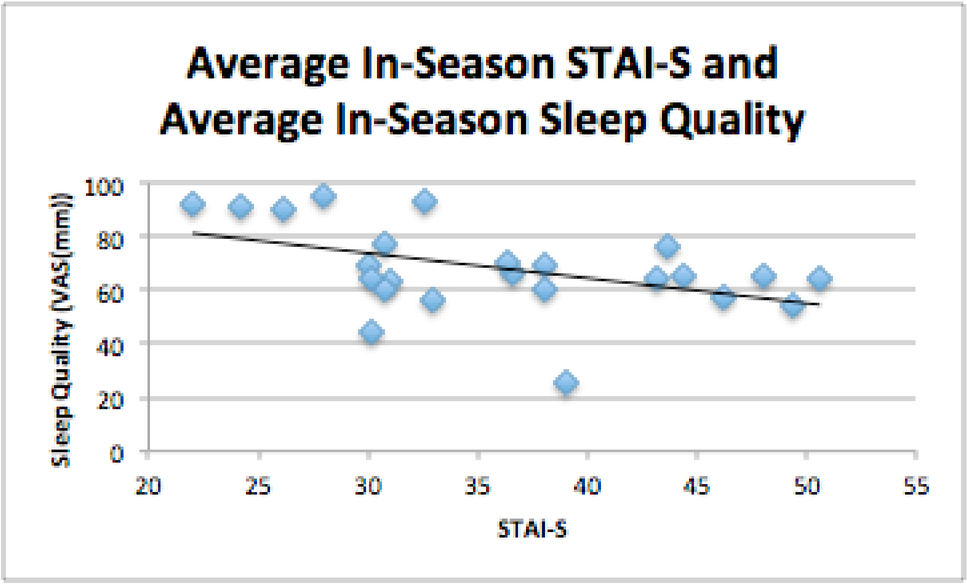

Figure 38. Negative correlation between average in-season anxiety state and sleep quality

DISCUSSION

The aims of the present study were to acquire objective sleep and performance data for varsity football athletes and to see if poor sleep the night before a game led to a decrease in performance on game day. Due to the athletes' poor sleep in and out of the competitive season, additional relationships were examined between sleep measures and self-reported personal health information.

While no major changes in sleep values were noted, there was a trend towards increased objective total sleep time and total bed time in-season and a significant decrease in subjective night pain and present pain in-season. The trend towards increased objective total sleep time is similar to the findings among a group of elite Australian Rules football players.[7] Compared to baseline, their sleep times increased on the night before their game, as was seen among the varsity football players.[7] Due to the fact that there is a trend towards more sleep time, but no change in sleep efficiency, Richmond et al.'s suggestion that the Australian Rules football players' discipline and proper preparation for a game may also hold true among the participants in our study.[7] While they do attempt to get a better night's sleep in the sense of sleeping for a longer period of time, there is something impeding them from achieving better sleep efficiency. In contrast to German athletes' sleep habits, where 65.8% had worse sleep at least once before a competition or game in a 12 month period, the present study does not show a decrease in total sleep time, sleep efficiency, sleep quality or wake after sleep onset, the night before a game.[71]

Alongside no significant changes in sleep variables came no change in performance measures from off-season to in-season. In comparison with other game day performance testing studies, this study is unique, being the only one to our knowledge that collects objective performance data in and out of season. While the 21 NCAA football players had physical testing throughout their final season game, they had no baseline pre-season measures to compare to in order to see if the players were performing at their peak abilities.[72] Through our study, we were able to measure performance prior to the possible deteriorations created by the season, i.e. injuries, overtraining with workouts and practices and fatigue caused by their rigid schedule, entailing school, training, practice, work and family/social life. While there was a trend towards increased total sleep time, this did not affect performance results as seen among 11 NCAA basketball players that were required to increase their objective total sleep time throughout the season, creating a significant improvement in performance, decreasing reaction time and sprint time, and increasing free throw and 3 point shooting accuracy.[73] Also, although no decrease in sleep quality was seen among our participants, decreases in a group of young female adults were correlated to a decrease in flexibility, muscular endurance and cardiovascular fitness; therefore, there is a possibility that the football players' already low sleep efficiency and quality values may be evidence of sub-maximal performance results during both seasons.[5]

Previous performance testing studies provide for comparisons to be made between the football players and other athletic and age-matched groups. In comparison with competitive male college athletes, the football varsity athletes scored better in the agility t-test (9.94±0.50sec versus 9.4±0.9sec and 9.3±0.8sec) and the vertical jump test (63.34±11.17cm versus 65.6±12.2cm and 67.4±9.8cm).[51] Moreover, the vertical jump test results were comparable to nose tackle, defensive tackle, defensive end, inside linebacker, strong safety, offensive center, offensive guard, offensive tackle, tight end, and quarterback positions at the NCAA Division 1-A football level (results ranging from 63.00 to 75.95cm).[48] Although the age range of our participants do not match-up with the age brackets supplied in the reference values for hand strength, the varsity football players' have a greater strength than males aged 25 to 34 (61.1±10.9kg and 63.5±13.3kg versus 54±3kg).[59] When compared to males ranging in age from 20 to 50 years, their strength exceeds their 49.5±10.1kg grip strength.[53] Last, when compared to Division 1 NCAA football players, the varsity football players' reaction time test scores were superior (203±20ms versus 187.2±28.5ms and 180.5±26.8ms).[52]

Studies have proposed that athletic populations have better sleep parameters compared to the regular population, suggesting that exercise can help improve sleep.[35] This was documented among male soccer players and their non-athletic counterparts; the soccer players had better subjective sleep among the two groups.[35] When our participants were compared to their non-athletic university student counterparts, this phenomenon was not present. Rather, the sedentary students' average baseline sleep efficiency was much higher (88.9±4.3%), as was their average sleep efficiency after being induced with delayed onset muscle soreness via an eccentric shoulder exercise (87.4±5.2%). In both instances, the non-athletic population is above the healthy 85% sleep efficiency, whereas the football players are not.[74] Recently, research looking at sleep duration and quality in elite athletes versus their non-athletic counterparts provided similar results.[75] The athletes' sleep efficiency was significantly lower than their non-athletic counterparts (80.6±6.4% versus 88.7±3.6%).[75]

Although there were no changes in sleep efficiency and performance measures, the alarming sleep efficiencies in (77.6±7.2%) and out (77.5±7.9%) of season were shockingly low. When compared to other studies looking at sleep efficiency in athletic populations, these averages are lower than the norm. The baseline sleep efficiency among ballerinas averaged 81.1±4.3%, higher than our baseline and in-season values; yet, their values one week before their premiere (78.6±4.6%), when high levels of physical and mental stress were present, are similar to those seen in the football players.[6] Also, sleep efficiency reported from a group of Australian Rules football players was also significantly higher than in the present study (88.0±3.8%).[7] This finding raises questions, as 70% of Brazilian Paralympic athletes who were categorized as having poor sleep quality had an average sleep efficiency of 78.5% calculated through the ESS questionnaire.[76] This similar result puts into question if the football players may not be fully rested during the off-season and the in-season. Moreover, 9 overreached swimmers averaged 81.58±4.41% sleep efficiency, causing a 5%

decrease in swim times; this value is significantly higher than baseline and in-season sleep efficiencies among the football players, questioning the presence of overreaching in the off-season, leading up to and during the in-season.[42]

When compared to non-athletic populations with medical conditions, the comparisons between the sleep variables are astounding. Among a group of cystic fibrosis and severe lung disease sufferers, their sleep efficiency averaged 71±25%, which is also well below the healthy cut-off of 85%.[77] More shockingly, their wake after sleep onset was much lower (69.6±58.1minutes) versus the football players' (108.2±39.3minutes and 106.7±54.9minutes), raising questions as to what is causing this healthy, athletic population from maintaining sleep throughout the night.[77] Also, when compared to a group of postpartum depressed women, the football players' sleep efficiencies are much lower than the women's 87.64±5.36%.[78] Last, a group of chronic pain patients also had better sleep efficiency than the football players, averaging 81.10±18.05% over a 2-week period.[79]

In order to better understand the possibilities of their decreased sleep efficiency throughout the off-season and in-season, the correlations between the sleep questionnaires and subjective sleep data was of interest. In the in-season, especially on day 5, there was a positive correlation between levels of self-report fatigue and PSQI, STAI-T and STAI-S. Therefore, those who have worse sleep quality via the PSQI are complaining of more fatigue, showing that they are not feeling rested, especially on the night before the game. Also, their anxiety levels, generally (STAI-T) and specifically on the morning of the game (STAI-S) correlate to their fatigue; this can be interpreted as not resting well the night before the game because of mild anxiety levels felt due to the presence of a game. In turn, with fatigue increasing as PSQI increased, alertness decreased, creating a negative correlation with PSQI. Alertness was also negatively correlated to STAI-T and STAI-S. Therefore lower levels of sleep quality and higher levels of anxiety caused the players' alertness to be decreased. If an athlete is suffering from higher levels of anxiety, and his alertness is decreased, there is a possibility that the lack in concentration may impact his ability to attentively receive instructions from the coaches and perform his duties on the field. Last, and most interestingly, anxiety was negatively correlated to sleep quality. We noted on average during the in-season and the off-season that the players' sleep quality decreased with higher levels of anxiety trait and state. This may shed light on the reason why this group of varsity football players is not sleeping as efficiently as other healthy groups. The presence of their rigid schedule and necessity to manage many activities during the day may be the cause of their overall mild levels of anxiety, causing for decreased sleep quality.

CONCLUSION

Although exercise is said to have positive benefits on sleep, the low sleep efficiencies of football players during the off-season and the in-season are concerning.[2, 5, 34, 35] Low sleep efficiencies have been seen previously in other athletic groups who are overtrained, therefore future studies monitoring training and sleep of the student-athletes is important in order to see if the phenomenon of overtraining is causing decreases in sleep hygiene.[41, 42] Student-athletes have very rigid schedules, encompassing school, studying, work, training, practices and a social/family life; time may be taken away from regular and healthy sleep schedules, therefore decreasing sleep efficiency and sleep quality and increasing daytime sleepiness, as was seen in this group, based on the Epworth Sleepiness Scale questionnaire.

Considering the amount of attention and resources that are spent on coaching, training and nutrition in football, sleep quality is an area of interest that is currently lacking. Providing athletes with information about sleep hygiene is a necessity. As is seen in table 5, their bedtimes are very late, with large ranges, which can negatively affect their sleep quality.[80] Also, as many athletes share housing, their bedrooms may become multipurpose rooms, being used as a place to study, eat, watch television, and relax; these activities may cause difficulty for the athletes to use their room for its primary purpose, creating difficulty falling asleep at regular times and maintaining efficient sleep. Future studies are needed to examine sleep in football, as this group not only showed poor sleep efficiency, but presented bad sleep quality based on the PSQI, increased levels of daytime sleepiness based on the ESS and mild levels of anxiety based on the STAI-T and STAI-S. Also, looking at their daily activity levels may provide insight on their training status and if overtraining is present, causing decrements in their performance. The use of polysomnography may add vital information about sleep in this athletic population, answering more questions about their sleep hygiene and how to improve sleep in order to achieve optimal physical and cognitive performance.

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APPENDIX

Additional Results

In addition to the correlations presented in the study, other correlations were made between mood and PSQI, STAI-T and STAI-S; night pain and STAI-T; and present pain with STAI-T and STAI-S.

When comparing mood with PSQI, STAI-T and STAI-S, negative correlations were present. PSQI (M=5.95 SD=3.05) was negatively correlated with day 5 in-season mood (M=68.83 SD=19.49), *r*=-0.441, *p*=0.031, *n*=24 (see figure 1). STAI-T (M=34.91 SD=7.12) was also negatively correlated to average in-season mood (M=64.67 SD=21.52), *r*=-0.470, *p*=0.021, *n*=24 (see figure 2); and day 5 in-season mood (M=68.83 SD=19.49), *r*=-0.500, *p*=0.013, *n*=24 (see figure 3). Average off-season STAI-S (M=35.10 SD=8.45) was negatively correlated to average off-season mood (M=65.80 SD=22.24), *r*=-0.547, *p*=0.006, *n*=24 (see figure 4), as well as average in-season STAI-S (M=35.93 SD=9.39) being negatively correlated to average in-season mood (M=64.67 SD=21.52), *r*=-0.451, *p*=0.027, *n*=24 (see figure 5).

Night pain and present pain were positively correlated to anxiety. STAI-T (M=34.91 SD=7.12) was positively correlated to in-season average night pain (M=17.56 SD=21.94), *r*=0.425, *p*=0.038, *n*=24 (see figure 6). STAI-T (M=34.91 SD=7.12) was positively correlated with average in-season present pain (M=22.87 SD=22.93), *r*=0.525, *p*=0.008, *n*=24 (see figure 7). Average in-season STAI-S (M=35.93 SD=9.39) positively correlated to average in-season present pain (M=22.87 SD=22.93), *r*=0.427, *p*=0.037, *n*=24 (see figure 8).

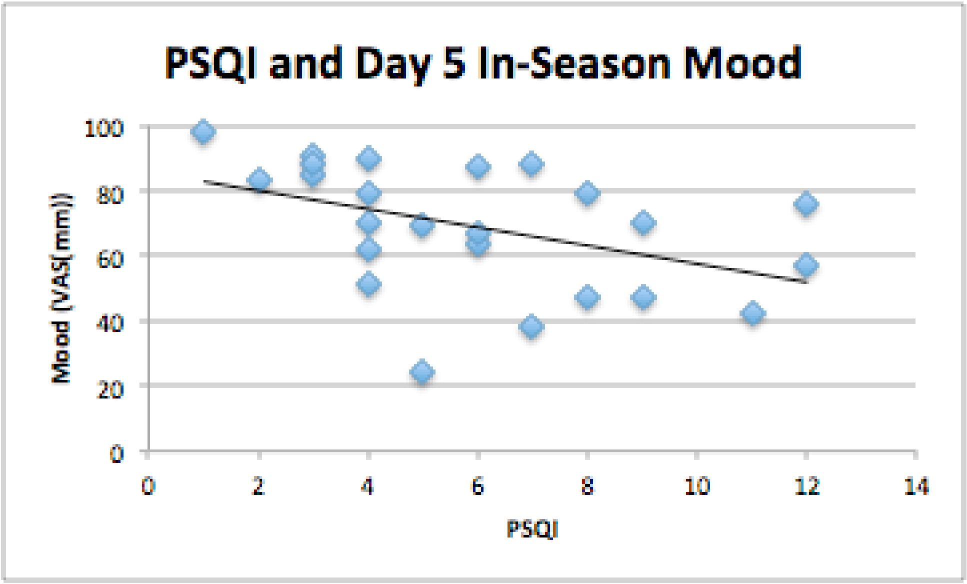

Figure 1. Negative correlation between subjective sleep hygiene and day 5 in-season mood

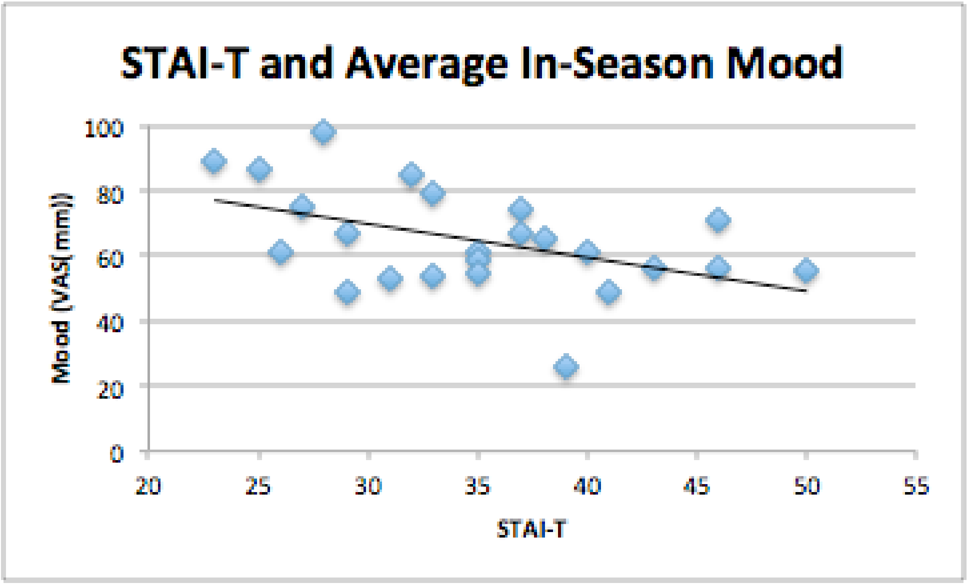

Figure 2. Negative correlation between anxiety trait and average in-season mood

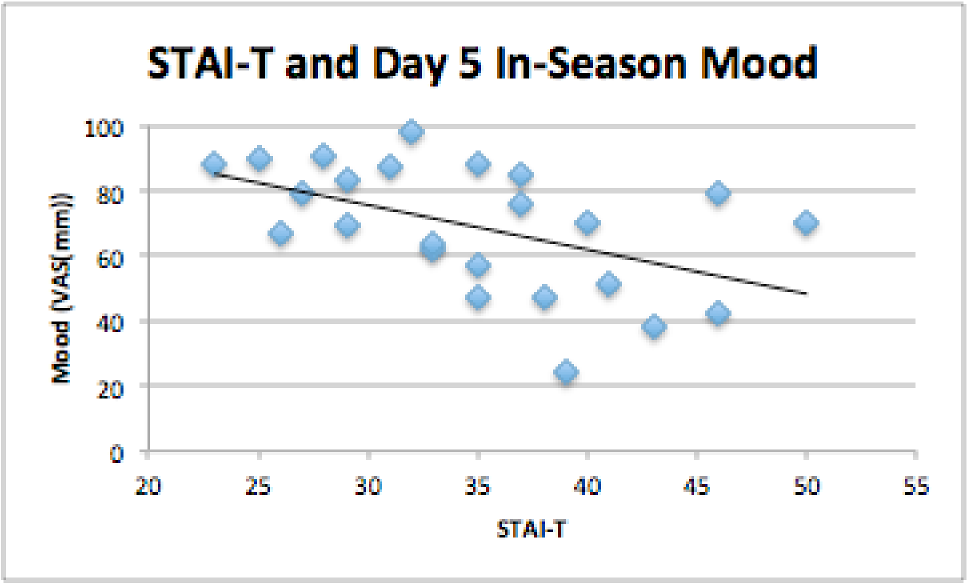

Figure 3. Negative correlation between anxiety trait and day 5 in-season mood

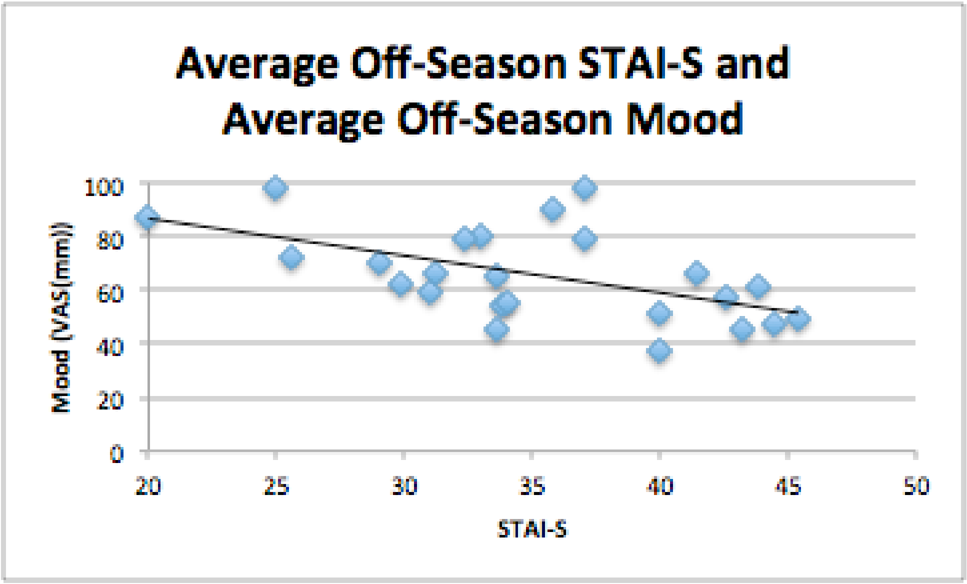

Figure 4. Negative correlation between average off-season anxiety state and mood

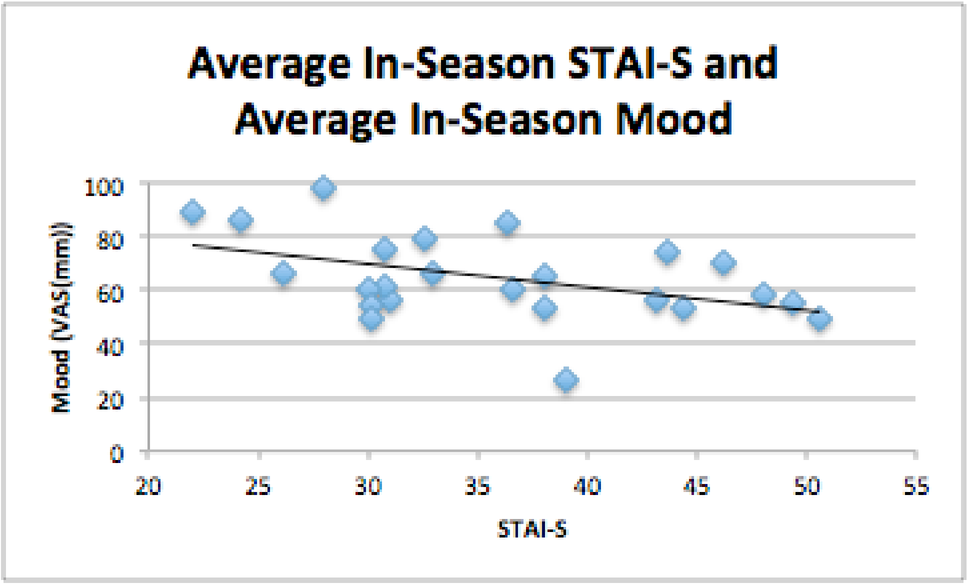

Figure 5. Negative correlation between average in-season anxiety state and mood

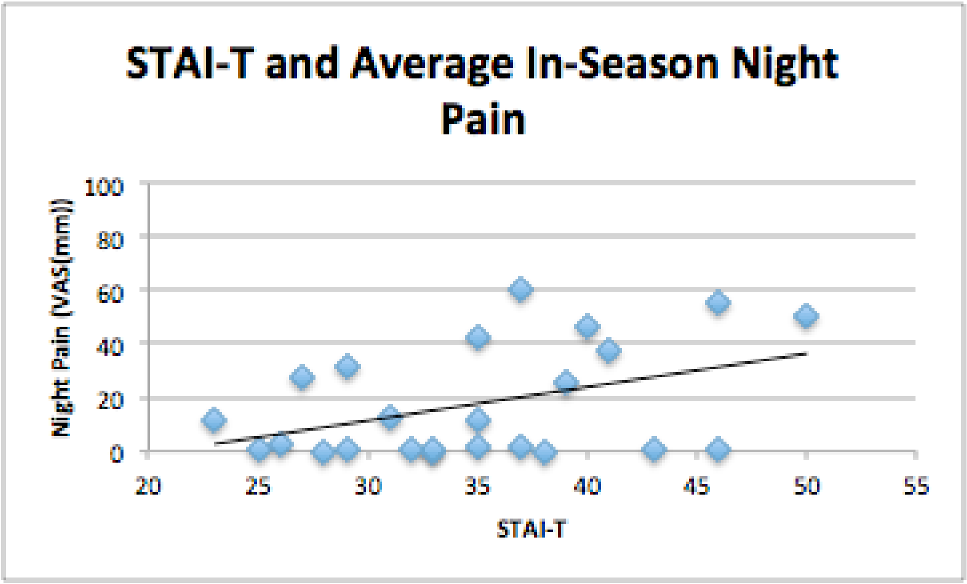

Figure 6. Positive correlation between anxiety trait and average in-season night pain

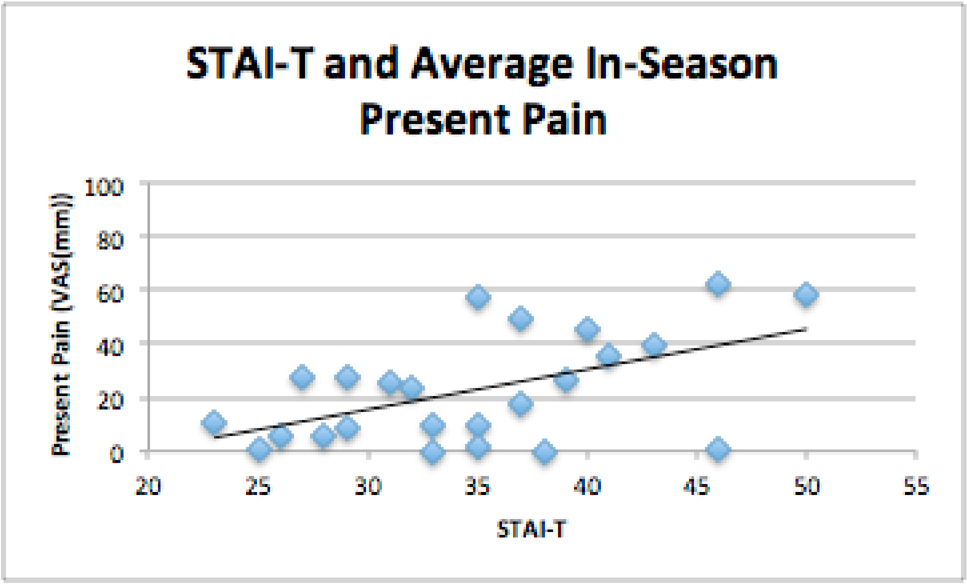

Figure 7. Positive correlation between anxiety trait and average in-season present pain

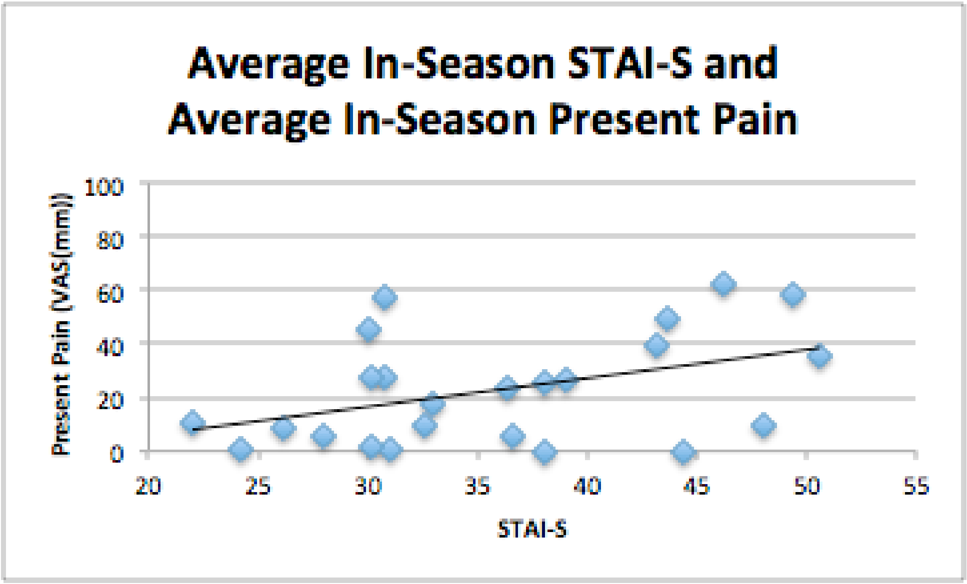

Figure 8. Positive correlation between average in-season anxiety state and present pain