Injured Athletes Self-Report Poor Sleep, More Pain and Increased Anxiety

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Abstract

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After injury athletes self-report poor sleep and increased pain and anxiety

There is a reciprocal relationship between pain and sleep but there are only a few studies that measure the direct effect of pain on sleep. In addition, athletes often suffer from painful injuries but there is no information on how their pain affects their sleep and recovery. Finally, in naturally occurring pain conditions, the influence of anxiety is unclear. Therefore, the purpose of our study was to measure the influence of pain and anxiety on sleep in athletes. We used a one group, pre-post test design. Eleven collegiate athletes completed both the injured phase and healed phase (6 females and 5 males; height=175.2cm (10.3), mass=81.3kg (23.0) age= 21.0yrs (1.4)). We measured their function, pain, anxiety, subjective sleep measures, and actigraphy measures of sleep at both phases. Our athletes experienced a significant reduction in pain, and a significant improvement in function in the healed phase compared to the injured phase. In addition, anxiety improved from a medium level to a weak level. Moreover, our athletes had significant poorer self-report sleep quality during the injured phase compared to the healed phase. In conclusion, self-reported sleep was worse after suffering an injury compared to sleep during the healed phase but actigraphy measurements were not different between the two phases. It seems evident that our athletes' sleep hygiene need to be improved to be able to further investigate the pain/sleep relationship in our athlete. Finally, according to our findings anxiety seems to be an important factor in athletes' sleep but is rarely measured.

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Introduction:

Pain and sleep have a complex and reciprocal relationship.[36] Over the past decade, the quantity of research exploring the pain and sleep association has sharply risen.[36] Most authors state that a perpetual circle of pain and poor sleep can be created which will eventually impact the biological and behavioural well-being of the individual.[19, 100] Previous studies have examined a multitude of patients suffering from; tension headaches, migraines, primary insomnia, primary depression, and pediatric chronic pain.[36] Authors have suggested that daytime pain can decrease sleep quality and poor sleep worsens the pain experienced the following day.[2, 11] The relationship between pain and sleep may not be that clear since most research in this area assessed the sleep→pain directional effect. An example of the sleep→pain direction includes inducing sleep deprivation and measuring the increase in pain the following day.[36] There are very few studies that evaluate the unidirectional pain→sleep effect, for example inducing pain in healthy subjects and measuring the resultant effect on sleep.[36] It is possible that sleep disturbance is a stronger predictor of future pain than pain of sleep disturbance but there is a paucity of research in the pain→sleep area and it is unclear what the relationship is on pain on healthy sleepers.

There is little research on induced pain→sleep in healthy people especially naturally occurring acute pain which may affect the amount of anxiety experienced by the subject. One study that examined the pain→sleep direction suggested that burn patients with poor sleep quality reported higher pain intensity during the night and upon awakening.[82] However, pain was not the only sources of awakenings reported by patients but also nurses, noise, roommate and more.[82] Patients with shoulder impingement syndrome (SIS) had higher scores on the Pittsburgh Sleep Quality Index compared to healthy control group which suggests patients with SIS had lower sleep quality.[100] It is hard to compare most pain→sleep studies because of methodological differences and the types of injuries including acute and chronic injuries. The difference between induced pain studies and a naturally occurring injured pain condition is that subjects are informed about the pain stimulation which may affect their anxiety about the painful stimulus. There is an established relationship between increased anxiety and poor sleep.[87] In addition, there is a relationship between anxiety and pain, for example in patients with a soft-tissue injury to the neck and increase in anxiety has been related to a more painful outcome.[12] This may be especially true in athletes, where athletes may experience different amounts of anxiety from the regular population.[110] Therefore in naturally occurring pain conditions it is unclear how pain and anxiety affect sleep.

Athletes often suffer from musculoskeletal injuries where pain is the number one symptom but the effect of pain from injury on sleep is unknown.[77] In the United States only and in the year of 2006, the number of anterior cruciate ligament (ACL) surgeries was estimated at 105,118 with an increase trend,[64] and each one of them had significant pain. Sleep is important in athletes because poor sleep can affect athletes physiologically and slow down or modify their tissue healing process by decreasing glucose tolerance,[97] and changing the pattern of rhythmic secretion of testosterone.[62] It is possible that poor sleep in athletes could reduce the effectiveness of their rehabilitation. In addition, the anxiety experienced by an athlete during an injury may affect their sleep. In a previous study done on postoperative orthopedic patients, pain following surgery was 6.6±1.6 on the visual analogue scale and patients self-reported poor sleep quality on following night, a mean value of 9.2±3.5 on the Pittsburg Sleep Quality Index.[19] But this study examined patients who knew they were going to receive surgery, so the anxiety will not be reflective of a naturally occurring injury. In addition, a naturally occurring injury that does not require surgery is more common and the previous study only used self-report measures for sleep. Therefore the purpose of our study was to measure pain and anxiety in athletes who have suffered an acute injury, and note the changes in sleep.

Literature review

Epidemiology of injury and time loss following an injury

Participation levels in sport

Every year, the number of collegiate student-athletes increased.[5] Between 2006-2007, the National Collegiate Athlete Association reported for the first time a participation level of over 400,000 students-athletes.[5] Football was the sport with the most participants reaching a value of 62,459 student-athletes followed by basketball with 29,486 participants.[5] Participating in different sports is beneficial to anybody because physical exercise increases fitness, motor coordination and improves social skills.[1] However, playing any sport could increase the likelihood of injuries.[1]

Incidence of acute injuries in hockey and football

Acute injuries increased as participation in sports increased.[1] During a 7 year period, male hockey players sustained 2828 injuries while female hockey players sustained 767 injuries.[3] Over the 7 year period, there was a 7.8% increase in practice injury rate for men and 7.2% increase in practice injury rate for women.[3] For football, during one season, there was a total of 3459 injuries that occurred during practice and games for 55 NCAA schools.[93] Also, 1811 injuries events occurred over a period of 5 year in 5 Canadian West University men's football teams.[66] Over the course of a football careers, the estimated risk of sustaining an injury is anywhere from 11% to 81%.[101] The increased injury rate could be due to more intense training or participating in multiple sports in one season, thus increasing the opportunity for acute injuries.[1]

Mechanism of injury

Physical contact has become the dominant cause and mechanism of injury in sport.[30] Hockey is considered a high-speed collision sport where there is contact between players and other objects, such as the boards.[3] Forty-eight percent of injuries sustained by players, in men`s collegiate hockey, were the result of physical contact between players.[3] In basketball, physical contact has become a normal component during game and the main cause of player injury at 52.3%.[30] Football is also considered a high-impact collision sport, with injuries occurring in both contact (78%) and noncontact (8.9%) situations during games.[29] Physical collisions don't only occur in games but also in scrimmage practices where they simulate game-like conditions.[31] There was an almost fivefold increase in acromioclavicular joint injury in scrimmage practices compared to regular practices due to physical contact.[31] In summary, physical contact between players could lead to serious injury to any of the five general body parts: head/neck, upper extremity, trunk/back, lower extremity and other/system.[3, 29, 30]

Main injured area within athletes

The majority of injuries reported in all sports was to the lower extremity.[3, 29, 30] In men's collegiate football, more than 50% of all injuries were to the lower extremity. The two main areas were the knee (internal derangement) which accounted for 17.8% and ankle (ligament sprain) which accounted for 15.6%.[29] In a similar study on men's collegiate basketball, the most common injury occurred at the ankle (ligament sprain) which accounted for 26.2% and the knee which accounted for 7.4%.[30] However, shoulder separations were also seen in men's collegiate hockey.[3]

An injury definition and an approximation of time loss following the injury

For an injury to be reported to the Injury Surveillance System (ISS), it must satisfy three criteria.[31] The injury must have occurred as a result of participation in an organized National Collegial Athletes Association (NCAA) intercollegiate practice or competition. The injury must also have required medical attention and resulted in restriction of the student-athlete's participation in practice or competition for at least one calendar day beyond the initial day of injury.[31]

Most injuries resulted in 10 days or more of restricted or total loss of participation.[29] In professional football, an average of 18 days was missed following an ankle sprain.[109] In collegiate football, 51.6 % of practice-related injuries required 1 to 6 days of recovery and 49.7% of game-related injuries required 7 days or longer.[93] In men's collegiate basketball, approximately 18% of both game and practice injuries resulted in a minimum 10 days of restricted participation.[30]

In conclusion, injuries can happen at any time while participating in sport. In clinical setting, the treatment of choice for injury to the extremities is to use a treatment known as RICE (Rest, Ice, Compression and Elevation) for the first 4-5 days to reduce pain and swelling. There were several thousand injuries last year meaning there were several thousand rehabilitation programs going on. Therefore, a lot of people could be affected by our study if we find out that sleep as a significant role to play in the healing process of the injury.

The relationship among pain, injury and sleep

Pain measurements

Pain is a subjective concept that can be defined only by the individual experiencing the pain[19] and the only way to successfully assess pain is to believe the patient.[108] Often, different subjects with the same trauma will report vastly different levels of pain.[74] Individual variation can happen at any stage in pain processing.[74] The disparity may start either from the peripheral nociceptors or through pain-regulating mechanisms in the brain and spinal cord or even from the psychological and cognitive processes involved in interpreting and experiencing pain.[74]

In research, the visual analog scale is a common tool for measuring pain intensity.[20, 24, 78, 79, 103] The scale consists of a single 100 millimeter line, where one end is marked with the label "no pain" and the other end as "worst possible pain".[58,20, 40] The line may be printed either horizontally or vertically.[58] The patient is asked to place a mark on the line at a point representing the intensity of his/her pain experienced at that moment.[58] A ruler is then used to measure the length between the start of the line and the pen mark and this distance represents the patient's pain level.[58]

The VAS is a simple and quick tool for measuring pain intensity and is applicable in a variety of clinical settings.[13, 103] The VAS was determined to be valid, reliable in assessing acute pain,[14, 26, 53, 103] and to have a high sensitivity, meaning the ability of the scale to detect change.[108] The minimum clinically significant difference on the VAS for change in acute pain intensity was determined to be 13mm within a group of 48 subjects who had a trauma and were admitted to a hospital emergency department.[103] They repeated pain measurements every 20 minutes for a total time of 2 hours.[103] However, in a similar study, they found that clinically significant changes in pain were not uniform along the entire VAS.[16] A total of 77 patients with an acute injury to the extremity who were admitted to the hospital emergency department within 24 hours post injury were enrolled in the study.[16] They measured pain every 30 minutes until patients were free of pain or discharged or a total of 2 hours had passed.[16] Patients with initial pain scores of 67mm or greater on the VAS experienced a clinically significant change in pain with a greater difference in VAS score (28mm±21) than those patients with initial pain within 34mm or less on the VAS (13mm±14).[16] In other words, patients with greater pain required a greater change in VAS score to achieve clinically significant pain relief.[16] Some have suggested that the significant benefit of the VAS is the continuous measure it provides, instead of a discrete value.[20] However, VAS requires adequate cognitive ability to translate a sensation of pain into a distance measure and therefore can be cumbersome to administer.[13] Also, according to a review on pain-rating scales, they showed that VAS data were not always normally distributed and repeated scores using this method varied by as much as 20% which could contribute to clinically significant reduction in pain.[108]

The numerical rating scale (NRS) is another subjective pain measurement which consists of an 11, 21, or 101 point scale where the end points are the extremes of no pain and worst pain.[108] The NRS can be graphically or verbally delivered.[108] When presented graphically the numbers are often enclosed in boxes and the scale is referred to as an 11 or 21 point box scale depending on the number of levels of discrimination offered to the patient.[108] This pain- rating scale has been shown to have a poor reproducibility[104] but a great sensitivity to change.[108] The NRS is a valid tool to use in clinical studies to measure acute pain.[13] Both scales have been used extensively with athletes.

Different pain intensity depending on the injury

Substantial pain was determined as a VAS score of 40/100mm and above.[73] A study done on acute pain patients mentioned that a score of approximately 30/100mm on the VAS corresponded with moderate pain and a score of 54mm or more corresponded with severe pain.[24] Mean pain intensity was 53.8/100 mm on the VAS in elite athletes with shoulder pain.[69]Average pain intensity was 65.9/100mm on the VAS following orthopedic surgery, such as total hip/knee arthroplasty, in 75 adults.[19] Pain in and around the knee following an anterior cruciate ligament (ACL) injury can be reported as being as high as 9.5/10 on the numerical rating scale (NRS).[98]

Awareness of pain during sleep

The perception of pain during sleep depends on the duration and type of stimulus.[56] While sleeping, a presumed gating process of somatosensory inputs is thought to prevent awakening from irrelevant input or non-life threatening events.[56] When a painful stimulus or clinical pain episode lasts long enough, the protective mechanism that maintains sleep continuity is released and a clear behavioral response may occur with a potential return to consciousness.[56] Longer-lasting or tonic painful stimuli similar to clinical pain seem to have an increased chance of eliciting a full-blown arousal response.[56] Long- lasting pain can be initiated by an increased excitability of nociceptive neurons found in the spinal dorsal horn following an injury.[77] Another possible mechanism could be through one of the dopamine pathways. Dopamine promotes and maintains state of arousal.[71] Consequently, dopamine is tied to the regulation of sleep and wake.[32] As a result, it was suggested that pain induced alterations in the dopamine signaling which might influence the raphe nuclei modulation of sleep and wake.[36]

The relationship between pain and sleep

Common sense dictates that if we are experiencing a painful stimulus, we will have difficulty to initiate and maintain sleep, yet this is rarely measured directly.[67] Within the general population, sleep problems are common but the occurrence within the pain population is striking.[67] Also, sleep disturbance was generally not considered a major problem for people until an injury was experienced; then pain and sleep became salient interacting issues.[56] Pain and sleep disturbances are two important complaints interacting in complex ways that ultimately impact the biological and behavioral well-being of the individual.[100, 19]

Research has mentioned a feed-forward relationship between pain and sleep where the daytime pain worsens the quality of sleep and the poor quality of sleep aggravates the pain experienced the following day.[2, 11] Non-restorative sleep was a contributing factor in lowering pain threshold thereby altering pain perception and sensitivity on following days.[59] This was observed in a group of healthy middle aged women who did not have any muscle discomfort and were sleep deprived of slow wave sleep.[59]

The incapacity to sleep at night is not always dependent of pain perception or severity.[52, 72] Inactivity, increased time in bed or daytime napping might occur as a way to cope with pain following an injury thereby creating transient sleep problems.[52, 72] This was observed in acutely injured people who became chronic pain patients.[52, 72] Moreover, attention to pain led to poorer and more disturbed night's sleep in 50 women who had primary fibromyalgia syndrome. When these women spent a day with more attention to pain, poorer and more disturbed sleep was observed which led to a cycle of increased attention to pain and poorer sleep.[2]

<u>Which one come first, pain or poor sleep?</u>

The beginning of pain, acute post-op or trauma, usually came first or overlapped with the onset of poor sleep.[86, 96] Chronic pain patients who were receiving treatment for their pain were interviewed by phone using retrospective questionnaires on issues pertaining to their pain and sleep quality. Twenty- three out of 51 subjects mentioned pain as the sole reason for their sleep disturbances.[96] The majority of the sample (53%) responded that they had never had sleep problems prior developing their pain condition.[96] Another study assessed the prevalence and magnitude of sleep disturbance in a sample of orofacial pain patients.[86] Out of 128 subjects, approximately 99 patients reported reduced sleep quality since pain onset.[86]

Sleep onset insomnia usually followed traumatic injury.[95] In burn patient, sleep onset insomnia was suggested as an important predictor of long-term pain as far as 2 years.[95] Also, insomnia symptoms seemed to be associated with aggravation of musculoskeletal pain from regional to a widespread condition.[44, 68] In study of 3171 adults who were free of chronic widespread pain (CWP) at baseline, were followed-up 15 months later to identify any new case of CWP.[44] At the follow-up, 324 subjects developed new CWP and after adjustment for age and sex, one of the three factors that predicted the development of chronic widespread pain was scoring nine or more on the Sleep Problem Scale which meant having poor sleep.[44]

Acute injury and sleep

Burn patients

Acute pain following a traumatic injury will result in a temporal circular relationship with sleep which was examined in burn patients.[82] Their purpose was to objectively evaluate sleep quality of burn patients and to investigate the daily temporal relationship between sleep disturbances and pain intensity.[82] Actigraphy was used for objective sleep measures, a visual analogue scale for subjective sleep quality and pain was measured using a visual analogue thermometer (VAT).[82] On average, burn patients slept for 332min (approximately 5.5h) with high numbers of awakening and long-awakening, which was defined as poor sleep. Also, the pain level of burn patients at night varied between 0-10 with an average of 2.6±2.6 VAT.[82] The highest pain level was recorded 30 min following therapeutic procedure with an average of 3.6±2.8 VAT.[82] Longer wake time and frequent awakenings were predictors of higher pain intensity during the same night, on the following day upon awakening and during therapeutic procedures.[82] Subjective estimations of sleep fragmentation and reports of lower sleep quality were also predictors of higher pain intensity at night and during the following day.[82] The results also showed a significant relationship between daytime pain and sleep measures on the following night, where higher procedural pain intensity was a predictor of sleep duration and fragmentation during the following night.[82] However, discomfort (18.7% of night awakenings) and pain (13.0%) were not the only sources of awakenings reported by patients.[82] Other reasons were nurses (16.7%), noise (7.5%), roommate (6.4%) and more.[82]

Post-surgery pain

Patients reporting intense pain post operation had greater incidence of clinically significant postoperative sleeping problems.[19] One study investigated postoperative night-time pain and sleep quality on orthopedic patients on the second postoperative day. In the assessment, patients' night-time pain was determined to be severe and their quality of sleep was poor.[19] Patients' night-time pain was reported to be 6.59 ± 1.62 on the visual analogue scale (VAS) and their quality of sleep was 9.24 ± 3.53 on the Pittsburgh Sleep Quality Index (PSQI) which was referred as poor sleep.[19] Sleeping in an unfamiliar bed, the inability to perform their usual routines, and feelings of anxiety or pain were most reported as complaints of poor sleep.[19] Also, poor sleep quality was suggested to be related to high pain intensity scores, roommates, and noises in orthopedic wards.[19] A statistically significant correlation ($p \leq .05$) was found between patients' night-time pain intensity (VAS) and quality of sleep (PSQI).[19] However, this study only measured one night of sleep and used subjective sleep measurements. Many factors other than pain were influencing the quality of sleep of the subject.

Shoulder pain

Patients with acute shoulder pain complained of sleep disturbances.[100] Patients with shoulder impingement syndrome (SIS) were evaluated subjectively using the Pittsburgh Sleep Quality Index (PSQI) and the Shoulder Disability Questionnaire (SDQ).[100] Patients had higher scores on the PSQI compared to a healthy control group, 11.57±4.34 and 4.82±2.66 respectively, which implies patients with SIS had lower sleep quality.[100] Shoulder impingement syndrome seems to disrupt the sleep quality significantly.[100] Deterioration of the sleep quality in these patients was correlated with pain scores assessed by Shoulder Disability Questionnaire.[100] Thereby, their findings suggested a strong correlation between poor sleep quality and pain severity.[100] This study only collected subjective data following one appointment where two questionnaires were filled out. However, they did compare their experimental group with a control group.

In the literature, there is little information on athletes' sleep and acute injury. We know that athletes are more prone to injuries compared to the general population as mentioned before. Also, increased sleep allows for better sports performance.[28] Good sleep is a very important component for athletes if they want to achieve great success in their sport. At the moment, we are hypothesizing that sleep might be an important factor to include in a fast return to play following an acute injury due to the strong connection with pain.

In conclusion, many studies suggested a strong connection between acute pain and sleep. Poor sleep was a contributing factor to an increased pain sensation.[59] However, pain can also be a causal factor to poor sleep.[2, 11] Thus, sleep and pain have a feed-forward relationship, also described as a perpetual vicious circle.

Identifying the relationship between pain and sleep is difficult because of the wide variety of methods used to induce pain and measure sleep. For example, chronic pain may cause poor sleep, but the cause behind the increase in pain may be confounded by the poor sleep.[96] In addition, other studies noted poor sleep in acute conditions, but they just measured self-report sleep. Sometimes people have a worse self-report of their sleep quality than they are actually sleeping.[85]

Possible factors for poor sleep reducing tissue healing

Poor sleep and altered physiology

Voluntary sleep curtailment has become common to create maximum time for work and leisure activities.[17] Experimental extension of the time spent in bed to 14 hr per day over 1 month showed that a normal 8 hr night did not meet the sleep needs of healthy young adults.[106]

In the past, evidence suggested that the primary function of sleep was cerebral restoration;[10, 97] but today sleep is also known to have an impact on peripheral function.[97] Having good sleep will provide a normal regulation of numerous biological aspects, maintain vital physiological functions, promote homeostasis, learning and memory and physical recovery.[27, 83]

Glucose clearance impairment following sleep restriction

As little as one week of sleep curtailment was associated with striking alterations in metabolic and endocrine function in healthy young people.[97] During the sleep-deprived condition, which was 4 hours of sleep for 6 nights, a clear impairment of carbohydrate tolerance was observed.[97] The rate of glucose clearance in the sleep-deprived condition was 1.45% per min which was nearly 40% slower than in the sleep recovery condition, which was 12hours of sleep for 6 nights, and a rate of 2.40% per min.[97] The sleep-deprived condition resembled glucose tolerance values typical in older adults with impaired glucose tolerance which are around 1.60% per min,[39] whereas values for the sleep recovery condition were typical of fit young adults (2.2–2.9% per min).[80] In addition, the acute insulin response to glucose was 30% lower during the sleep-deprived condition than in the sleep recovery condition, 304pmol/min vs. 432pmol/min respectively.[97] The metabolic and endocrine alterations during the sleep-debt condition seem to mimic some of the hallmarks of ageing, suggesting that chronic sleep loss could increase the severity of age-related pathologies, such as diabetes and hypertension.[97]

Sleep physiological influence on tissue healing

A sleep dept can also impair muscle recovery.[27] Strained muscles required significant molecular changes to allow damaged cells to recover or be replaced by news cells.[84] Insulin-like

Growth Factors 1(IGF-1) are a central element in the stimulation of muscle protein synthesis, thus promoting muscle growth.[90] Testosterone is another important hormone which allows satellite cell proliferation and differentiation, a critical step in muscle recovery and growth.[65] Those two hormones were strongly influenced by sleep.[27] Sleep deprivation led to an increased cortisol secretion[105, 107] and a decreased testosterone[62] and IGF-1concentration.[27, 34] Thus, a highly proteolytic environment is created favoring the loss of muscle mass and hindering muscle recovery after damage induced by exercise or injury.[27]

In summary, poor sleep can alter the progression of tissue healing. Poor sleep can affect you physiologically and slow down or modify your tissue healing process by altering physiological functions. Therefore, our future findings could have a significant impact on the healing process of future injured athletes.

How to measure sleep

Polysomnography

The gold standard device of measuring sleep in a laboratory setting is polysomnography (PSG).[37] This testing device 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.[37] Recording data with the polysomnography requires a laboratory setting and laboratory technicians to monitors subjects.[60]As well, polysomnography is known to cause a first night effect defined as a decrease in the overall sleep on the first night of data collection. The first night effect was observed in a healthy population not suffering from sleep problems.[47]

Actigraphy

A commonly used alternative to polysomnography is a device known as actigraphy.[37] For the purpose of our study, we used actigraphy to measure sleep data. The actigraph is an objective, ambulatory monitoring method for tracking subject sleep/wake activity over time and looks like a wrist-watch but contains an accelerometer[102] sensitive to movement in all directions.[41] The accelerometer integrates the degree and speed of motion and produces an electrical current that varies in magnitude.[41] As the degree and speed of motion increase, the voltage that is produced increases, and this information is stored as an activity count.[41] This miniature computerized wrist-watch like device detects and logs wrist movement for an extended time period while patients are living in their natural environment.[41, 88] The actigraph can be set at different epoch times (15-30-60 seconds) depending on the researcher. (Respironics, Inc.) An epoch is defined as the period of time where acceleration is measured and summed up over that time period. (Respironics, Inc.)Then, the computer software of the actigraph scores all epochs as either sleep or wake. (Respironics, Inc.) To determine if a particular epoch is scored as wake, the computer software compares the activity counts for the epoch in question and those immediately surrounding it with the threshold value set by the researcher which can be either 20, 40 or 80 activity counts. (Respironics, Inc.) If the number of counts exceeds the threshold, the epoch is scored as wake. If it falls below, or is equal to the threshold, the epoch is scored as sleep (Respironics, Inc.) By comparing the amount of sleep/wake from the activity count, a multitude of sleep/wake measurements can be estimated.[89]

Through the actigraph, sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO) and sleep efficiency (SE) can be induced.[89] The amount of time an individual takes to fall asleep after going to bed is called sleep onset latency (SOL) and is measured by immobility.[23] Total sleep time (TST) corresponds to the amount of time spent sleeping during the sleep interval, from bedtime to wake time.[47] Wake after sleep onset (WASO) is defined as the time spent awake after falling asleep until the final awakening.[46] Finally, sleep efficiency (SE), represented as a percentage, explains how well an individual slept from sleep onset until final awakening.[89] In other words, sleep efficiency is categorized as the percentage of time in bed that was spent asleep.[89]

Actigraphy correlates well with polysomnography in measuring sleep parameters.[23, 47] More specifically, the Actiwatch Score (AS) (Actiware and Actiware CT, Respironics, Inc., Murrysville, PA) model, when worn on the non-dominant wrist, has shown to have very good interunit reliability (r=0.98) as well as recording comparable and reliable data for sample sizes using more than one AS for data collection (r=0.98).[41] Some research suggested that the actiwach could be worn on either the dominant or non-dominant wrist with no recording difference on sleep duration and activity measures.[23, 47] However, other research showed a difference between both sides with the dominant side recording higher amounts of activity.[23, 47] Moreover, the reliability was constant over long periods of time since the mechanical sensitivity of the actigraph did not significantly change.[47] Furthermore, actigraphy did not cause the “first night ” effect.[47]

Even if actigraphy has been validated in healthy populations, erroneous data collection can happen if certain procedures are not followed adequately.[23, 47] Actigraphy is less accurate than polysomnography when recording SOL and total sleep time, therefore while analyzing sleep measures extra precaution should be taken.[23] For this reason, a sleep diary is needed in conjunction with the actigraphy[47] to note measures such as bedtime, wake-up time, naps and time that the AS was removed for bathing purposes.[47] However, a study reported similar sleep efficiency (SE) and total sleep time (TST) between polysomnography and actigraphy set at medium sensitivity threshold.[75] The recorded values for SE and TST by the polysomnography were 90.7% and 434.7 min compared to 91.4% and 438.3min with the actigraphy.[75] As mentioned prior, actigraphy needs to be combined with a sleep diary.[47]

The main sleep diary used is called Pittsburgh Sleep Diary (PghSD) and measures daily activities and perceived sleep measures.[70] The sleep measures include: sleep duration, WASO, sleep quality, waking mood and alertness.[70] The PghSD is very reliable, with high inter-test correlation.[70] The diary must be filled out twice daily; once before bedtime and once upon awakening.[70]

Subjective sleep measurements

The Pittsburgh Sleep Quality Index (PSQI) subjectively assesses an individual's sleep disturbances and sleep quality.[18] The questionnaire analyzes sleep quality, sleep duration, sleep efficiency, sleep disturbance, sleep medications and daytime dysfunction.[18] The PSQI allows the researcher to discern good from poor sleepers.[18] The components of the questionnaire are very reliable, with a reliability coefficient of 0.83.[18] Overall, the PSQI is a useful tool to tell apart good and poor sleepers. Scores can range anywhere from 0 to 21 but a score of more than 5 categorizes bad sleep.[18]

The Epworth Sleepiness Scale (ESS) is a tool used to measure an excess of sleepiness and daytime sleepiness.[48] The questionnaire includes eight different scenarios. Subjects need to rate how likely they are to fall asleep on a scale of 0 to 3. The lowest score means no chance of dozing and a score of 3 represents a high possibility of dozing.[48] If the summation of the responses equals 9 or more than that individual is very sleepy and needs medical advice.[48] The ESS has high validity, reliability and internal consistency.[49] In a study on professional ballerinas' sleep quality, they used the ESS to measure ballerinas' sleepiness throughout their test period and they reported a mean ESS of 7.6.[35]

Anxiety

The State-Trait Anxiety Inventory (STAI) is a known measure of anxiety.[50] Two distinct anxiety concepts can be measured with STAI: state anxiety and trait anxiety.[50] State anxiety (STAI-S) subjectively measured the presence and severity of current symptoms of anxiety.[50] Trait anxiety (STAI-T) subjectively measured a generalized propensity to be anxious.[50] While filling out state concept, participant had to answer the statements according on how they feel right now, at this moment.[50] The statements were “I feel calm”, “I feel secure”, “I am tense”, just to name a few. However, for the trait concept participants had to indicate how they generally feel. Those statements were “I feel pleasant”, I feel nervous and restless”, “I feel satisfied with myself” and so on. Participant had to score each statement with a value between 1 to 4; one means “Not at all”, two means “Somewhat”, three means “Moderately so”, and finally four means “Very much so”. Each concept contains 20 statements. Scoring above 40 in either concept has been suggested to detect clinically significant symptoms of anxiety.[54]

Anxiety is closely related to sleep where an increase anxiety has been shown to be associated with poor sleep.[87]According to a study, a mean value of 36.73 on STAI-S and 33.87 on STAI-T was enough to demonstrate the relationship between anxiety and poor sleep.[76] Those values were obtained following one night of partial sleep deprivation in healthy volunteers who were recruited from an University.[76] The partial sleep deprived participants had to wake up 4h before their usual rising time.[76] In addition, acute sleep deprivation in eighty-eight healthy people has been shown to increase their subjective anxiety.[7] The acute sleep deprived participants were instructed to stay awake through the night and they did not know in advance in which group they would be, either the control or experimental group.[7] This ensured that none of the participants changed their behavior before coming to the laboratory.[7] It was suggested that sleep deprivation might be correlated with changes in mood because of the overlapping roles of the hypothalamus.[7]

Disability questionnaires

In our study, in addition to measuring the pain intensity level, we also measured their level of disability. Although there have been many questionnaires developed to measure disability, only two were used in our study. Disability of the upper extremity was measured with the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, and disability of the lower extremity was measured with the Lower Extremity Functional Scale (LEFS).

Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH)

The DASH was developed to measure symptoms and physical function in patients with upper extremity musculoskeletal conditions.[45] Thirteen previously developed scales were reviewed, and 821 items identified.[45] After further testing, the questionnaire was reduced to 30 items that assess the patient's ability to perform certain tasks ("open a tight or new jar", "push open a heavy door", "place an object on a shelf above your head").[45] The scoring was also standardized to a five-point Likert-type scale.[43] The total score for the scale ranges from 0 (no disability) to 100 (severe disability).[43] The DASH has been determined to be valid, reliable, and responsive to both small and large changes in disability in both proximal and distal upper extremity musculoskeletal disorders.[43] The minimum important change on the DASH has been found to be 10 scale points, or 10% change.[43]

Lower Extremity Functional Scale (LEFS)

The LEFS was developed in an effort to find a valid and reliable measure of self-reported disability that could be applied to a variety of lower extremity musculoskeletal conditions in both research and clinical settings.[15] One hundred and seven physical therapy patients who suffered from any lower extremity musculoskeletal condition, including sprains, strains, fractures, dislocations, and osteoarthritis tested the scale.[15] By looking at other disability questionnaires, seventy-seven functional limitation items were identified.[15] These items were reduced to 22 by grouping similar activities and the final questionnaire contained 20 items.[15] Patients are instructed to rate the ease or difficulty of performing specific tasks ("squatting", "walking 2 blocks", "sitting for 1 hour").[15] Each item is scored on a five-point scale from zero to four, with zero representing extreme difficulty and four representing no difficulty.[15] By summing up each individual item, a total score is obtained which indicates the level of function the patient currently has.[15] The LEFS has been determined to be a valid and reliable measure of lower-extremity function, and has been found to be more sensitive to change than previous measures.[15, 81, 111] The minimal clinically important difference is nine scale points, or 11.25% change.[15]

Literature review summary

In summary, we were interested in contributing to the knowledge gap on the pain→sleep directional effect and gaining valuable information on the possible relationship between pain and healthy sleepers. While there is a general consensus on the relationship between pain and sleep, very few studies are actually conducted in the pain→sleep direction. This is particularly important in athletes because of their increase chance of sustaining an acute musculoskeletal injury which also meant naturally occurring acute pain. We were aiming for this specific type of pain that spontaneously occurs with no warning so that we can also get an accurate measure of anxiety for the athlete at this time. Knowing the negative association between anxiety and sleep, it was evident to us that adding a measurement of anxiety would be very valuable to our analysis.

Objective

Our first objective was to measure pain, function, and anxiety in athletes who suffered an acute injury. Then using self-report questionnaires and actigraphy we measured sleep in athletes over the 7 days following the acute injury which we refer to as the "injured phase". Once the athlete had recovered from the injury, we used the same self-report questionnaires and actigraphy to measure sleep again during the "healed phase". We gained valuable information about the effects of acute injury and pain on sleep. Eventually, this line of research will allow us to offer individualized rehabilitation for athletes and their management of sleep.

Pittsburgh Sleep Quality Index (PSQI)	To subjectively assess an individual' sleep disturbances and sleep quality
Epworth Sleepiness Scale (ESS)	To measure an excess of sleepiness and daytime sleepiness
State-Trait anxiety Inventory – State (STAI-S)	To measure to presence and severity of current symptoms of anxiety
State-Trait anxiety Inventory – Trait (STAI-T)	To measure a generalized propensity to be anxious
Beck's Depression Inventory (BDI-II)	To examine the participant's level of depression
Total Sleep Time (TST)	The amount of time spent in bed attempting to sleep between bedtime to get up time
Total Bed Time (TBT)	The total amount of sleep obtained during a sleep period
Sleep Onset Latency (SOL)	The period of time between bedtime and sleep onset time
Wake After Sleep Onset (WASO)	The amount of time spent awake after sleep has been initiated until final awakening
Sleep Efficiency (SE)	The percentage of time in bed that was spent asleep

Table 1. Scales and some sleep variables commonly used in this study.

Hypotheses

1) Athletes would experience a significant reduction in pain, and a significant improvement in function between the injured phase and the healed phase.
2) Athletes would score significantly poorer on PSQI, ESS, STAI-S, STAI-T, and BDI-II during the injured phase compared to the healed phase.
3) Athletes would have significantly poorer self-report sleep measures such as sleep quality, fatigue, mood, TST, TBT, SOL, WASO and SE during the injured phase compared to the healed phase.
4) Athletes would have significantly poorer actigraphy measures such as TST, TBT, SOL, WASO and SE during the injured phase compared to the healed phase

Methods

Research Design

We used a one group, pre-post test design. After an athlete experienced an injury, we measured their function, pain, PSQI, ESS, STAI-S, STAI-T, BDI-II, subjective sleep measures and actigraphy sleep measures. Once the injury resolved and the athlete returned to play (returned to practice or competition), we recorded the same measurements of function, pain, sleep, and anxiety.

Subjects and subject follow-up

We recruited varsity athletes from Concordia University during their in season and who were starters or least dressed for games. Inclusion criteria included any athlete who suffered a painful injury occurring as a result of participation in a varsity games or practices. The injury required medical attention and resulted in restriction of the student-athlete's participation for at least one game or practice. In our study, athletes missed on average of 19 days (13) after the initial injury. We excluded subjects from the study if they consumed irregular amounts of alcohol or any recreational drugs for the duration of the study. Some of our participants did consume alcohol during the study but the principal investigator was informed and did not used that day during the analysis. However, participants were asked to keep the actiwatch one more day to compensate. Also, as varsity athletes they could be control at any moment for drugs consumption, therefore we were certain that none of our athletes consumed any illegal substances during our study. In addition, exclusion criteria included any medical conditions or diagnosed sleep disorders that would affect their sleep.[96] Once again, as varsity athlete they need medical clearance before starting the season, therefore any condition such as insomnia, restless leg syndrome or sleep apnea could have been reported in their medical file. None of our participants complained of any sleep disorders or were treated for these problems.

Data collection was mainly possible due to good communication with many athletic therapists working with different varsity teams at Concordia University. The PI received forty-nine cell phone text messages to inform her that an athlete has been injured. Only 32 injured athletes were able to be seen within the 24 hours window since some injuries happened during games played outside of town. Of those 32 subjects, twelve subjects did not complete the injured phase of the protocol for the following reasons: three athletes did not miss any game following their injury which was part of the exclusion criteria; three athletes appeared to not have wear the watch according to what was shown on the actogram; three athletes withdraw for personal reason; one athlete did not record any pain on his journal; one athlete did not fill out his journal properly, therefore too many data were missing; and finally one athlete's watch did not function properly for unknown reason (see figure 1). Out of the 20 athletes who finished the injured phase of the study, only 11 completed the healed phase. There were three athletes who graduated before they could start the healed phase; three athletes simply did not want to continue for personal reason; two athletes were still reporting pain after 6 weeks and the in-season was done and finally one athlete never answered any calls and never came back to rehabilitation before the end of the season.

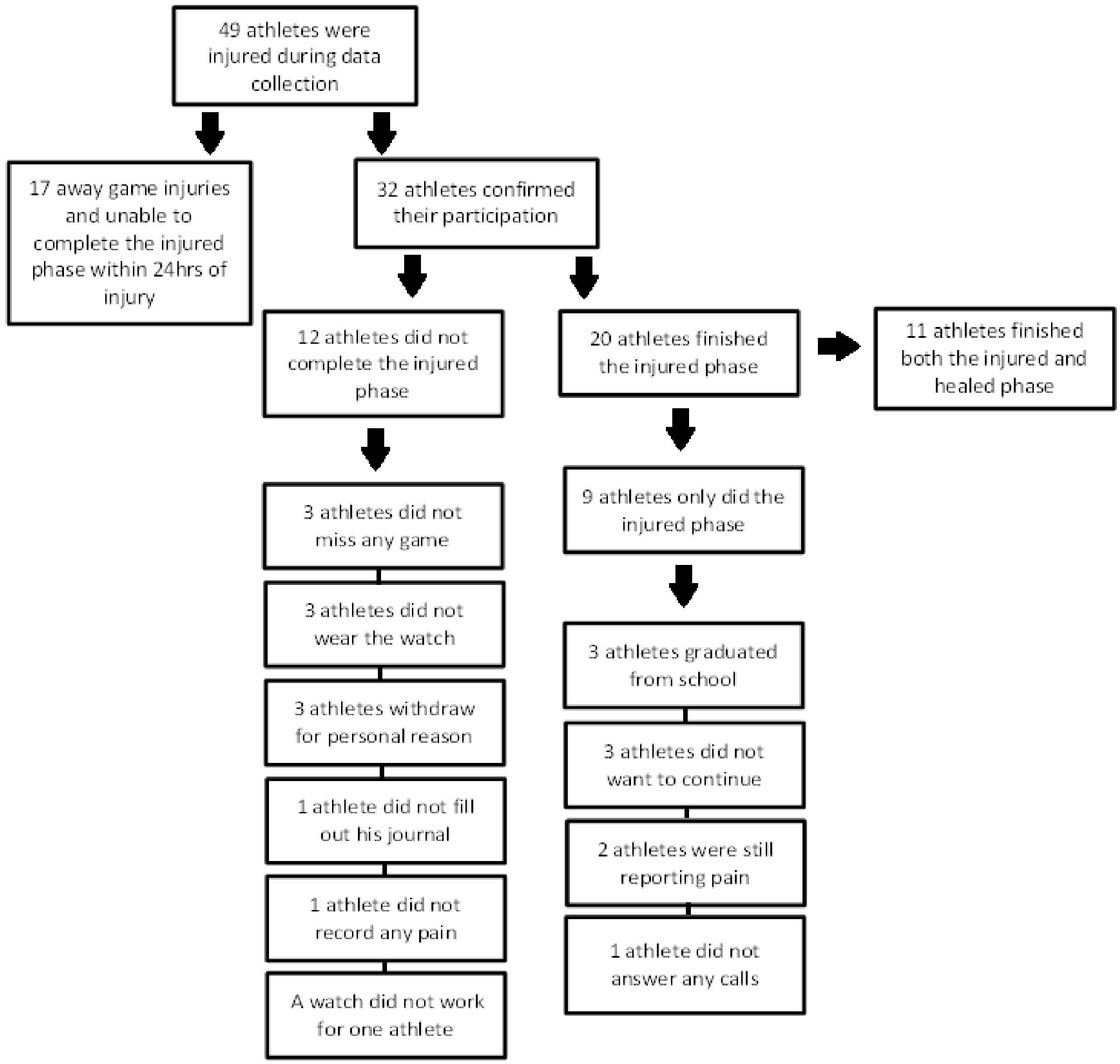

Figure 1. Consort Diagram of our final sample.

The final sample for the injured phase of the protocol consisted of 14 males and 6 females. The mean age of the sample was 21.4yrs (1.8), their mean height was 178.6cm (9.7) and their mean weight was 90.7kg (25.2). The total sample that completed both phases of the study was comprised of 5 males and 6 females. The mean age of this group was 21.0yrs (1.4), their mean height was 175.2cm (10.3) and their mean weight was 81.3kg (23.0). All demographics data are shown in table 2.

	Injured phase	Healed phase
	n=20	n=11
Age (years)	21.4 ± 1.8	21.0 ± 1.4
Height (cm)	178.6 ± 9.7	175.2 ± 10.3
Weight (kg)	90.7 ± 25.2	81.3 ± 23.0
Female	6	6
Male	14	5
Sport		
Basketball	2	1
Football	11	5
Hockey	2	2
Rugby	4	2
Soccer	1	1
Upper Extremity Injury	4	1
Finger	1	0
Wrist	1	0
Shoulder	2	1
Lower Extremity Injury	16	10
Foot	1	0
Ankle	5	2
Knee	7	5
Thigh	2	2
Hip	1	1

Table 2. Characteristics of athletes by group (mean± SD)

Measures

Pain and function assessment

We used the Pittsburgh Sleep Diary to assess sleep and a few other variables in our athletes. This sleep diary contained a visual analogue scale for pain. Every morning, athletes reported their amount of pain felt throughout the night and their present pain after awakening. We then measured from the point zero (no pain) up to their mark. All pain scores were recorded out of 100 mm. Therefore we had a present pain score representing pain during the day, and a night pain score that represented the amount of pain felt throughout the night.

We used the DASH or LEFS questionnaire to evaluate the level of dysfunction in our athletes. The athletes completed the DASH questionnaire if they had an upper extremity injury. The DASH measured their symptoms and physical functions.[45] The DASH score ranges from 0 (no disability) to 100 (severe disability).[43] However, we reversed the DASH scores so that 0 meant severe disability and 100 meant no disability to be able to compare their score with the

LEFS questionnaire. The athletes completed the LEFS if they had had a lower extremity injury. The LEFS measured their self-reported disability.[15] The LEFS score ranges from 0 (severe disability) to 80 (no disability). However, we adjusted the score so that 0 meant severe disability and 100 meant no disability to be able to compare their score with the DASH questionnaire.

Self-reported sleep and sleepiness

We administered the Pittsburgh Sleep Quality Index (PSQI) questionnaire to collect subjective information on the participants' sleep hygiene; a total score above 5 meant they had a poor sleep quality.[18] The PSQI contains 7 components; the first component was subjective sleep quality, the second component was Sleep onset latency, the third component was Total sleep time, the forth component was Sleep efficiency, the fifth component was Sleep disturbances, the sixth component was Sleep medication and the last component was Daytime functioning. We also administered the Epworth Sleepiness Scale (ESS) questionnaire to survey the participants' daytime sleepiness; a score of 9 or greater indicated above average daytime sleepiness.[48, 49]

Anxiety and Depression

We measured anxiety by using the State-Trait Anxiety Inventory (STAI).[50] The STAI is reliable for investigation of non-clinical levels of anxiety,[33] and can measure two distinct anxiety concepts which are state anxiety and trait anxiety. State anxiety (STAI-S) subjectively measured the presence and severity of current symptoms of anxiety and trait anxiety (STAI-T) subjectively measured a generalized propensity to be anxious.[50] Scoring above 40 has been suggested to detect clinically significant symptoms of anxiety.[54] Finally, we administered the Beck's Depression Inventory (BDI-II) questionnaire to examine the participants' level of depression; a score above nine signified clinical concern.[9]

Daily sleep journal

As mentioned earlier, we used the Pittsburgh Sleep Diary to assess self reported sleep in our athletes. The Pittsburgh Sleep Diary was used as a daily journal and contained seven morning sheets and seven night sheets. 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, ratings of sleep quality, mood, alertness, fatigue, and as mentioned earlier night pain and present pain.[70] Ratings of sleep quality, mood, alertness, fatigue, night pain and present pain were scored on the VAS. The bedtime sheet included meal times, the amount and time of caffeine ingestion and cigarette smoking, the use, time and dose of medications, exercise type and amount, length of naps, and the removal of the actigraphy device for bathing purposes.[70] The Pittsburgh Sleep Diary contained all the information necessary to obtain subjective sleep measures including; total sleep time (TST), total bed time (TBT), sleep onset latency (SOL), wake after sleep onset (WASO) and sleep efficiency (SE). We obtained TBT by counting the number of minutes between the bedtime and the wake up time as reported by the athlete. Then, we were able to get TST by subtracting the number of minutes taken to fall asleep (SOL) reported by the athlete and the numbers of minutes awaken after the sleep onset (WASO) also reported by the athlete. Next, we obtained SOL and WASO directly from the journal. Finally, we calculated SE by dividing TST by TBT.

Actigraphy measures of sleep

We used actigraphy to objectively measure sleep in the athletes.[4] All participants wore the Actiwatch Score (AS) (Actiware and Actiware CT, Respironics, Inc., Murrysville, PA) on their non-dominant wrist[23, 41, 47] or, if the athlete had an upper extremity injury, the watch was worn on the un-injured arm. The athletes wore the AS for 24 hours a day for 7consecutive days. However the athletes removed their AS when bathing, since water could damage the accelerometer.[70] While wearing the AS, we instructed our athletes to follow their regular daily routine and we allowed them to actively participate in practices or games, but they had to remove the AS to prevent any damage to the watch or injury to other players. We permitted naps during the data collection period, but they needed to record them in their daily sleep diary. Participants of the study had their sleep measurements taken twice: once during the injured phase and once during the healed phase. The AS was set at 1-minute epoch which meant that acceleration was measured on an arbitrary scale and summed over that time period. The AS scored all epochs as either sleep or wake. To determine if a particular epoch is scored as wake, the AS compared the activity counts for the epoch in question and those immediately surrounding it with the threshold value set at 40 activity counts. If the number of counts exceeded the threshold, the epoch was scored as wake. If it fell below, or was equal to the threshold, the epoch was scored as sleep (Respironics, Inc.) By comparing the sleep/wake amount, a multitude of sleep/wake measurements were estimated. Similar variables were calculated from the journal but here we used data from the actiwatch to calculate; sleep onset latency in minutes (SOL) (period between bed time and sleep onset)[42], total sleep time (TST), wake after sleep onset (WASO) (time spent awake after initial onset of sleep)[42], total bed time (TBT) and sleep efficiency (SE)(percentage of time in bed spent asleep).[42]

Procedures

We started subject recruitment during the fall 2013 semester and we finished during the winter 2015 semester. To participate in the study we only asked athletes who suffered an acute injury while playing a varsity game or practice. As soon as an athlete suffered an injury, the principal investigator (PI) was contacted and an assessment of the injury occurred within 24hrs. Once the PI determined the athlete met all inclusion criteria, including missing time due to the injury, the PI informed the athlete about the study and provided the consent form. All consenting athletes received an AS and sleep diary and completed the following questionnaires: either the DASH or LEFS depending if the suffered an upper extremity or lower extremity injury, and the PSQI, ESS, BDI-II, STAI S, STAI T. We asked our injured athletes to wear the watch for 7 days following the injury day starting immediately (within 24 hrs of initial injury), to fill out the sleep diary every night before going to bed and every morning upon waking up. On the 7th day or as soon as possible the athletes returned the AS and sleep journal.

When the athlete was healed and returned to play, he or she was asked to meet again to receive the AS and sleep diary and to redo the 7 days protocol. They followed the same procedure as in the 7 days injured phase. Once again, on the 7th day or whenever possible, athletes returned the AS and sleep diary.

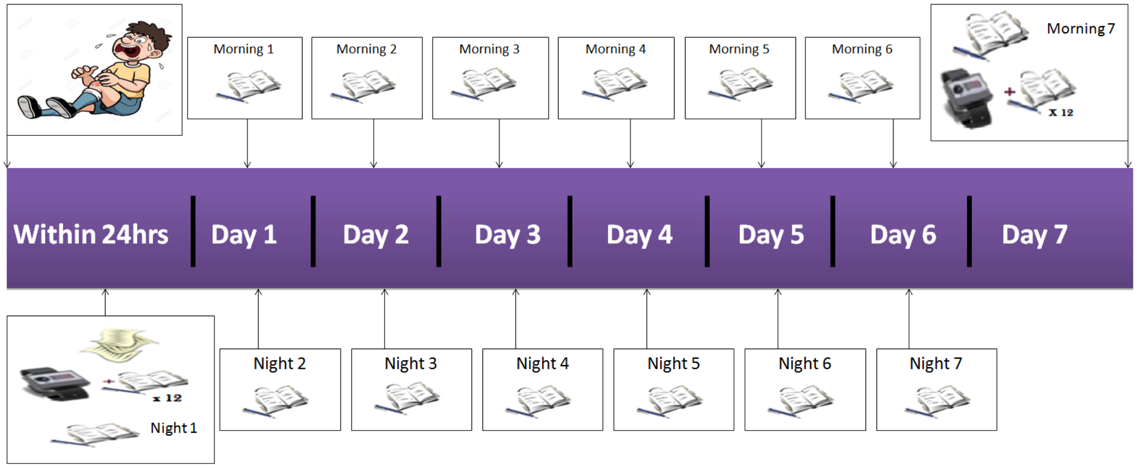

Figure 2. Data collection procedure including watch allocation and sleep journal recordings.

Statistical Analysis

We compared night pain, present pain and function using dependent t-tests during the injured phase and the healed phase. We also compared overall scores of the PSQI, ESS, STAI-S, STAI-T and BDI-II using dependent t-tests during the injured phase and healed phase. Moreover, we compared all sleep measures using dependent t-test between the two phases. The sleep measures were averaged over the 7 days and included: subjective SQ, fatigue, mood, alertness, TST, TBT, SOL, WASO, SE, bed time and wake time and actigraphy TST, TBT, SOL, WASO and SE. Some athletes did not wear the watch for a day or did not fill out the journal for an entry. So instead of averaging over 7 days we averaged over the 6 usable days. There was never more than one entry missing in all the data for any one subject.

All data were analyzed using the Statistical Package for the Social Sciences (SPSS 22.0 for Windows, SPSS Inc., Chicago, IL).

Results

Comparison between the injured and healed phase for pain and function

We compared night pain and present pain between the injured and healed phase. There was a significant decrease in both night pain and present pain in the healed phase. During the injured phase, athletes reported on average 26.8mm (16.6) of night pain compared to 4.4 mm (6.8) of night pain during the healed phase ($p=0.002$). Similarly, athletes reported 31.8mm (14.1) of present pain during the injured phase compared to 4.2mm (6.6) of present pain during the healed phase ($p<0.001$). Once again, we compared the mean score on the functional questionnaire during the injured phase to the mean of the healed phase. The mean for the injured phase was 40.5 % (20.2) compared to 88.5 % (13.2) on the healed phase (p<0.001). This confirmed the first hypothesis that after suffering from an acute injury and completing rehabilitation, athletes experienced a significant reduction in pain, and a significant improvement in function.

	Injured phase	Healed phase	N	p
Functional capacity scale (%)	40.5 ± 20.2	88.5 ± 13.2	n= 10	<0.001
Night pain (mm)	26.8 ± 16.6	4.4 ± 6.8	n= 11	0.002
Present pain (mm)	31.8 ± 14.1	4.2 ± 6.6	n= 11	<0.001

Table 3. Comparison of functional capacity scale and pain (mean±SD)

<u>Comparison between the injured and healed phase for all the questionnaires</u>

Following our analysis, we found that the mean PSQI score significantly decreased during the healed phase (p=0.011). They scored 5.2 (1.5) during the injured phase compared to 3.9(1.3) during the healed phase, where a score above 5 meant they had a poor sleep quality.[18] According to this result, athletes reported a significant improvement in their quality of sleep during the healed phase when they started full contact practices and games. Then, we analyzed the different components of the PSQI. The components that changed the most were the following; Subjective sleep quality (p=0.167), Sleep efficiency (p=0.138) and Sleep medication (p=0.138). While they were not statistically significant themselves, these three were the one that changes the most compared to the other components. Of note, this was a small sample size, eleven to be exact. For example, one subject changed their medication to three times or more per week to nothing in the last month. Moreover, we found a similar result with the ESS questionnaire where both phase were also significantly different (p=0.034). They scored 7.6(3.2) during the injured phase compared to 6.2(2.5) in the healed phase. Both scores were below average daytime sleepiness[48, 49]; nevertheless athletes reported a significant improvement in their daytime sleepiness during the healed phase. The other comparison that was significant was with anxiety as measured by the STAI-S questionnaire. They scored 36.7(11.7) during the injured phase compared to 27.6(5.2) during the healed phase. The significant decrease in the STAI-S indicates their anxiety level improved from a medium level to a weak level by the healed phase. However, no significant change was observed with the BDI-II questionnaire. According to their score, there was not any clinical concern of depression during both phases.[9]

	Injured phase	Healed phase	N	p
PSQI	5.2±1.5	3.9±1.30	11	0.011*
PSQI_SE	86.6±12.7	91.9±3.6	11	0.204
Component 1	1.00±0.45	0.82±0.40	11	0.167
Component 2	0.91±1.04	0.82±0.87	11	0.676
Component 3	0.55±0.52	0.36±0.67	11	0.506
Component 4	0.46±0.93	0.00±0.00	11	0.138
Component 5	1.09±0.30	1.00±0.45	11	0.588
Component 6	0.55±1.04	0.09±0.30	11	0.138
Component 7	0.82±0.60	0.82±0.60	11	1
ESS	7.6±3.2	6.2±2.5	11	0.034*
BDI-II	4.7±2.6	3.9±4.2	11	0.386
STAI_S	36.7±11.7	27.6±5.2	11	0.023*
STAI_T	30.6±4.9	29.6±5.5	11	0.432

Table 4. Comparison of all questionnaires (mean±SD); * means $p<0.05$

<u>Comparison between the injured and healed phase for subjective sleep measures</u>

There was a significant improvement in athletes subjective sleep quality between the injured phase and the healed phase (p=0.014). They reported a mean of 63.8mm (10.2) during the injured phase compared to 73.61mm (12.68) during the healed, where 100 mm indicates a very good sleep quality. This result confirmed part of the hypothesis that athletes had significant poorer self-report sleep quality during the injured phase compared to the healed phase. Concerning the second part of the same hypothesis, only a trend was observed with fatigue (p=0.065). They reported a mean of 48.8mm (12.3) during the injured phase compared to 41.9(15.2) during the healed phase, where 100 mm meant very high level of fatigue. Similarly, a trend was also observed with mood (p=0.094). They reported a mean of 68.7mm (12.6) during the injured phase compared to 74.4mm (10.6) during the healed phase, where 100 mm meant very calm. Then, we examined the subjective total sleep time where we were expecting significant lower total sleep time during the injured phase. However, the analysis showed that there was not any significant change in total sleep time (p=0.927). If we studied the means more closely, during the injured phase, athletes reported longer subjective total sleep time, however this results was not significant (see table 4). We also thought that subjective total bed time would be significantly higher during the injured phase compared to the healed phase, but again we were not able to confirm this hypothesis. There were not any significant changes in subjective total bed time (p=0.668). Once again, if we looked at those means closer, during the injured phase, athletes reported shorter subjective total bed time (see table 4). In addition, no significant change was found with the wake after sleep onset (p=0.394). Our hypothesis was that WASO would have been higher during the injured phase compared to the healed phase; the means were 4.9min

(6.1) and 4.0min (8.2), respectively. Finally, no significant difference was noted with the sleep efficiency (p=0.279). The mean SE as calculated by the times in the journal was 96.5% (10.4) during the injured phase compared to 95.6% (2.9) during the healed phase. Our hypothesis was not confirmed since we expected to find lower sleep efficiency during the injured phase compared to the healed phase.

Subjective sleep measures	Injured phase	Healed phase	N	p
Sleep Quality	63.8±10.2	73.6±12.7	11	0.014*
Fatigue	48.8±12.3	41.9±15.2	11	0.065
Mood	68.7±12.6	74.4±10.6	11	0.094
Alertness	57.5±12.8	60.2±17.9	11	0.591
Total Sleep Time	451.9±37.9	450.9±40.1	11	0.927
Total Bed Time	469.2±48.4	473.4±50.7	11	0.668
Sleep Onset Latency	12.4±10.4	15.8±11.6	11	0.373
Wake After Sleep Onset	4.9±6.1	4.0±8.2	11	0.394
Sleep Efficiency	96.5±2.6	95.6±2.9	11	0.279
Bed time	24:16:00±1:03:00	24:27:00±1:05:00	11	0.427
Wake time	8:05:00±1:13:00	8:20:00±1:06:00	11	0.198

Table 5. Comparison of subjective sleep measures (mean±SD); * means p<0.05

Comparison between the injured and healed phase for actigraphy measures

In addition to comparing the self-report sleep measures, we also examined the actigraphy measures between the injured phase and healed phase and no significant differences were noted for most comparisons. Our hypothesis #4 was not supported as there was no significant change in total sleep time (p=0.447). Moreover no significant change was found with total bed time (p=0.823). However, there was a significant change with WASO (p=0.038) but this result was the opposite of our hypothesis. The actigraphy results suggested that athletes had a significant increase in WASO during the healed phase with 87.3min (21.2) compared to the injured phase, 76.6min (19.7) Finally, sleep efficiency was significantly lower during the healed phase compared to the injured phase (p=0.042). Once again, this result was the opposite of our hypothesis since athlete's sleep efficiency went from 83.9% (3.0) during the injured phase to 81.9% (3.3) during the healed phase. However, this 2% difference while statistically significant may not be clinically significant and will be discussed further in the discussion.

Actigraphy measures	Injured phase	Healed phase	N	p
Total Sleep Time	393.0±36.0	384.9±38.2	11	0.447
Total Bed Time	469.7±48.6	472.2±47.3	11	0.823
Sleep Onset Latency	21.5±10.4	21.3±14.9	11	0.971
Wake After Sleep Onset	76.7±19.7	87.3±21.2	11	0.038*
Sleep Efficiency	83.9±3.0	81.9±3.3	11	0.042*

Table 6. Comparison of actigraphy measures (mean±SD); * means p<0.05

Discussion

The aim of our study was to measure the influence of pain and anxiety from an acute injury on sleep in athletes. The actigraphy data did not support some of our hypotheses of pain causing poor sleep in the injured phase. However, our subjective data suggested significant improvement or a trend towards significant improvement in sleep during the healed phase. Therefore, our subjective data did support some of ours hypotheses. These data are discussed below and additional relationships were examined.

1) We observed a significant improvement in pain and function between the injured phase and the healed phase. The athletes in our study needed to experience a clinically significant amount of pain during the injured phase in order for us to address our research question and hypothesis that pain would cause poor sleep during the injured phase. In the present study, athletes reported a mean of 26.8mm (16.6) of night pain and 31.8mm (14.1) of present pain during the injured phase. Moreover during the injured phase, athletes reported a mean of 40.5% (20.2) on the functional scale. The mean for each specific functional scale where 40.8% (21.4) for the LEFS and 37.5% for the DASH during the injured phase. To give a general idea of how much pain and dysfunction that represented, adults with anterior cruciate ligament tears reported a mean of 20.6mm of pain pretreatment and a mean of 54.75% on the LEFS.[22] Therefore, the athletes in our study experienced a similar amount of pain and slightly more dysfunction compared to subjects with a torn ACL prior to surgery. We feel confident that this level of pain and dysfunction would be enough to see a difference in the sleep scores between phases. While there are other injuries that are more painful some of them require surgery which was an exclusion criteria for this study.

2) The mean PSQI score significantly improved from the injured phase to the healed phase, 5.2 (1.5) and 3.9 (1.3) respectively. Similarly, the mean ESS score significantly improved from the injured phase to the healed phase, 7.6 (3.2) and 6.2 (2.5) respectively. Moreover, athletes also significantly improved their anxiety score from 36.7 (11.7) during the injured phase to 27.6 (5.2) during the healed phase. Finally, the BDI-II score did not improve from the injured phase to the healed phase, 4.7 (2.6) and 3.9 (4.2), respectively.

There are few studies that evaluate sleep in people with musculoskeletal injuries, but their results could be significant. In a comparison to our PSQI scores in the injured phase, a previous study on adult with full-thickness rotator cuff tear reported a mean preoperative PSQI score of

11.70 (4.61).[6] Twenty-four weeks post-surgery, they reported a mean PSQI of 4.97 for those who used postoperative narcotics for a short term.[6] None of our injured athletes reached a PSQI score as high as 11. This high mean might be explained by a greater amount of pain experienced pre-surgery, approximately 60mm, and a prolonged used of narcotic before the surgery which was suggested in their study.[6] However, healthy university students reported a mean PSQI score of 4.56 during morning session which was not significantly different from the evening session with a PSQI of 5.06.[63] Those scores resemble more our PSQI score found during our both phases and we could advocate that our student-athletes were better sleepers during the healed phase with a score of 3.9.

Our mean ESS score during the injured phase was 7.6. We found that our score was similar or rather exactly the same score noted in a profession ballet dancers study.[35] Ballet dancers have intricate training requirement which affect their sleep-wake rhythm and they are at great risk of physical injury since they undergo extreme physical and mental stress.[35] The aim of the professional ballet dancers study was to investigate the sleep-wake rhythm and sleep quality during rehearsal phase prior to a ballet premiere.[35] However, no measurement of pain was reported which could have been similar to our mean pain score if such a measurement was recorded.

In addition, our mean ESS score during the healed phase (6.2) was similar to a previous study on healthy university students. [63] The author of the study investigated on sleep quality and temperament among university student.[63] For the purpose of their study students were randomly assigned to arrive at the laboratory at either 9:00a.m.or 9:00p.m.[63] Students reported a mean score of 6.69 during the morning session which was not significantly different from the mean score during the evening session (6.74).[63] These ESS scores suggest that our athletes did not suffer from extreme daytime sleepiness and reported equivalent daytime sleepiness compared to other athletes and students.

In comparison with our means STAI score, a previous study on university athletes who sustained an orthopedic injury reported a mean STAI-T of 46.02 (5.28) during pre-season screening and a mean STAI-S of 30.97 (10.24) following their recovery.[25] The difference in STAI score might be due to their amount of freshmen they had at baseline which was approximately 50%.[25] However, in this study no pain measurement was reported but they mentioned the average days missed which was 8.90 (13.31);[25] in comparison our mean days missed was approximately 19 days. This might suggest that they had a similar pain level to our athletes.

Our mean BDI-II during both phases was lower compared to a previous study that reported a mean BDI-II of 11.32 in college students.[21] Even if our athletes were in pain and missed a few days of training with their team, their depression level was still lower than the mean BDI-II in healthy college students.

Lastly, within all our subjective sleep measures, only self-reported sleep quality significantly improved from the injured phase to the healed phase, 63.8mm (10.2) and 73.6mm (12.7), respectively. But, there was a trend toward fatigue and mood improving as well. However the other scores including alertness did not change significantly.

In summary, our athletes were not suffering from depression or a clinical level of anxiety at any moment during our study. However, their anxiety level did improve from the injured phase to the healed phase and anxiety is known to affect sleep quality. Therefore this might suggest that the improvement of their anxiety led to the improvement in their self-reported sleep measures.

<u>Summary of the influence of pain and anxiety on self reported sleep</u>

3) In this study, we wanted to study the acute pain→sleep directional effect. In a recent review on the relationship between sleep and pain, there were surprisingly few prospective studies that had exclusively evaluated this direction, the effect of pain on sleep.[36] Conversely, the direct effect of sleep disturbance on pain sensitivity has been evaluated in a variety of studies.[36] Those studies supported the notion that sleep impairments were a stronger and more reliable predictor of pain than pain was of sleep impairments.[36] Therefore the overreaching conclusion of "there is a relationship between pain and sleep" is not enough anymore. It seems apparent that the relationship between sleep – pain is not the same as pain – sleep. We need to focus on trying to find how they are related and more specifically in the direction of pain on sleep. One of the challenges of measuring the influence of pain on sleep is that pain can only be defined by the individual experiencing it[19] and the level of pain experienced by different individuals suffering a similar trauma might also vary on a large range.[74] In our study, the athletes overall self reported poor sleep during the injured phase compared to the healed phase. This could be due to the increase in pain or anxiety the athletes experienced during the injured phase. Therefore a

mechanism of how pain can influence sleep is discussed below as well as the influence of anxiety on sleep.

One possible mechanism of how pain causes poor sleep is through one of the dopamine pathways. The promotion and maintenance of arousal states is essentially due to dopamine[71] which is also, consequently, tied to the regulation of sleep and wake.[32] There are numerous dopamine receptors in the ascending reticular activating system which is a critical sleep modulation region.[8, 61] The ascending reticular activating system includes the raphe nuclei located in the brainstem.[8, 61] Prolonged periods of sleep loss and larger disruption of sleep continuity observed in chronic pain patient might be due to a dysfunction in serotonergic raphe cells signaling alertness.[38] In addition, the well-known interaction of serotonergic and dopaminergic neurotransmission[51] and the profusion of dopamine receptors in the raphe nuclei,[8, 61] it was suggested that pain-induced alterations in the dopamine signaling might influence the raphe nuclei modulation of sleep and wake.[36] Having knowledge of this potential mechanism, we speculate that during the injured phase, our athletes may have had some disruptions in dopamine signalling which cause the athletes to feel like they did not sleep as well.

As mentioned before, anxiety is associated with sleep.[87] Most anxiety – sleep studies use the poor sleep influence on anxiety to identify the mechanism for the poor sleep. Acute sleep deprivation in healthy people has been shown to increase their subjective anxiety.[7] Sleep deprivation might be correlated with changes in mood because of the overlapping roles of the hypothalamus.[7] The hypothalamus has a role in the regulation of sleep as well as mood via the sympathetic system.[7] The inhibition of the anterior part of the hypothalamus (ventrolateral preoptic nucleus), which control states of arousal, may lead to disruption in sleep.[91] The neurochemicals such as serotonin or noradrenaline that inhibit the ventrolateral preoptic nucleus are also involved in changes in mood states.[7] Therefore, it is plausible that sleep deprivation can significantly affect the timing and production intensity of these neurochemical inhibitors and as result affect human moods such as anxiety. In our study, while our athletes did not have a clinically significant level of anxiety, they still self-reported poor sleep. As mentioned previously, a mean value of 36.73 on STAI-S and 33.87 on STAI-T was enough to demonstrate the relationship between anxiety and poor sleep.[76] In addition, our athletes did experience a significant decrease in anxiety between the injured phase and the healed phase. Thus, it is possible that the elevated levels of anxiety during the injured phase caused our athletes to have malfunctions in their neurochemical inhibitors leading to a disruption in the sleep/wake cycle and therefore they self-reported worse sleep during the injured phase.

4) One of the main aims of our study was to observe a significant improvement in actigraphy SE between the injured phase to the healed phase. Surprisingly, contrary to our hypothesis our athletes had a statistically significant higher SE during the injured phase compared to the healed phase, 83, 9% (3.0) and 81, 9% (3.3), respectively. In a previous study, the average sleep efficiency reported for team sport was 86.4% (4.8) and for individual sport was 85.9 % (6.1) which was not considered clinically different from one another.[55] In comparison, another study which quantified sleep in elites athletes also reported a mean sleep efficiency of 80.6% (6.4) where speed skating had the lowest sleep efficiency compared to the other sports with a mean of 77.2% (7.1).[57] Therefore, we confirmed that our athletes had similar sleep efficiency compared to other study using the same device and we do not feel that their sleep significantly worsened in the healed phase as the statistical analysis indicated for the actigraphy SE. To conclude, there seems to be no specific cutoff determined by clinical trials but in the general population a sleep efficiency (SE) of 85% is considered the adequate amount of sleep.[92]

It is current knowledge that healthy fit individuals have higher quality of sleep compared to healthy sedentary individual. However, when athletes' training loads are extreme the quality of their sleep might become disrupted.[94] In addition, the requirement for sleep needed for each sport might be different because they differ in training volume and intensity, training timetable, psychological stress of training and some athletes might combine training with study and work.[57]

Our athletes were also attending school and their sleep efficiency value was similar to college male students who were also attending school and had to work at the same time. Their sleep efficiency over a week varied from 87.5% to 75.1% and the mean sleep efficiency was 81.5%.[99] Our athletes even if they were suffering from an injury and had to deal with their training, study and work, they were still closed enough from the normal sleeper value. However, since their sleep efficiency was already lower than 85% during the healed phase, it is less likely that we would have observed a significant decrease in SE during the injured phase because of the already low SE of the student athletes in our study.

Sleep efficiency is the percentage of time in bed that was spent asleep. There are two variables that could affect this value which are sleep onset latency (SOL) or wake after sleep onset (WASO). In our study, WASO was significantly worse during the healed phase compared to the injured phase, 87.3 min (21.2) and 76.6 min (19.7), respectively. This might be the main reason of our low sleep efficiency during the healed phase which could not be cause by pain or discomfort but other factors. Similarly, the mean WASO reported in healthy athletes was 77 min (31) where once again speed skating had the worst WASO with a mean of 98 min (46).[57] Our mean WASO during the healed phase is almost exactly as their mean WASO. This comparison supports the fact that pain was not the main cause of wake after sleep onset in our group of athletes and in consequence pain was not the main factor for their low sleep efficiency. However, we suggest that their poor sleep hygiene is a main factor affecting their sleep efficiency. Their poor sleep hygiene was observed due to their highly variable bed times and wake times. During the injured phase, our mean bed time was 24:16:00 (1:03:00) and wake time was 8:05:00 (1:13:00). However, bed time was actually varying from 21:15:00 to 3:40:00 and wake time was varying from 5:00:00 to 12:00:00. During the healed phase, our mean bed time and wake time were similar to the injured phase, 24:27:00 (1:05:00) and 8:20:00 (1:06:00), respectively. Once again, their bed time varied from 21:10:00 to 4:00:00 and they had the same values for wake time. This clearly demonstrates how our athletes' sleep hygiene need improvement.

Our study did have some limitations. Our athletes were Canadian college level which means the influence of pain on sleep may be different in adolescents or professional athletes. In addition to the above limitation, our athletes primarily suffered lower extremity injuries which also meant that it is possible that we were unable to determine if pain effects sleep more in upper extremity injuries. Moreover, since many athletic therapists were involved, this also implied that different return to play criteria were used for our athletes. Therefore, some of our athletes might have return to play but were still feeling some residual pain from their injury which could explain the high variability in pain during both the injured and healed phase.

In conclusion, our athletes who suffered a painful acute injury improved their subjective sleep measures but did not enhance their actigraphy measures. It seems evident that our athletes' sleep hygiene need to be improved to be able to further investigate their pain/sleep relationship. In addition, more research needs to be done to find the best sensitivity threshold using actigraphy to use while measuring athletes that would correlate well with polysomnography. Finally, according to our findings anxiety seems to be an important factor in athlete sleep but is rarely directly measured.

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Appendix

Since we had significantly more people in our injured phase compared to the healed phase, we decided to analyze the injured phase separately. We were interested in the possible relationships between sleep, pain, and function just at the injured phase. If athletes who had higher levels of anxiety reported poor sleep or more pain during the injured phase, for example. In addition, we were interested in the relationships between sleep and change in function between the injured phase and the healed phase. So these relationships were examined as well. All of these exploratory analyses were not part of my thesis proposal, which is why we have added these data here in the appendix. We used multiple Pearson correlations to identify any significant relationships between night pain, present pain, function, STAI-S, STAI-T and mood with PSQI, ESS, BDI-II, subjective sleep measures and actigraphy measures. Moreover, we wanted to measure the influence of sleep on the change on function and pain. We used a several repeated measures ANOVA with each sleep variable as a covariate, to determine if any sleep variables were significant. Then, we wanted to measure the influence of function and pain on the change in sleep and two questionnaires. Again, we used a several repeated measures ANOVA with sleep quality, fatigue, actigraphy sleep efficiency, ESS and PSQI as covariates, to determine if function and/or pain were significant.

Relationship between sleep and function during the injured phase only

Injured phase subjective sleep measures in relation to function, sleep, anxiety and mood

There was a significant negative relationship between total sleep time and function (p=.010). When athletes had longer total sleep time, they were reporting lower score on the functional scale questionnaire. A similar result was found with total bed time (p=.026). Nothing else was found significant with function (see table 6). With night pain, only a positive trend was found with wake time. This meant athletes seem to report less pain throughout the night when they woke up early in the morning. Then, we examined present pain which had two significant positive relationships (p=.016). One of them was when athletes had a very low level of fatigue; they were also reporting a low level of present pain on their awakening. The second was when athletes recorded short period of total bed time; they also reported low level of present pain on their awakening. However, only a positive trend was found with total sleep time (p=.081). In addition, we found a significant positive relationship between sleep quality and STAI-S (p=.007) which did not make sense since that would be interpreted as athletes reporting better sleep quality when they scored higher level of anxiety on their questionnaire. Finally, there was a significant positive relationship between sleep quality and mood on final awakening (p=.001). When athletes reported high sleep quality; they were also reporting feeling more calm. Also with mood, there was a positive trend with alertness, meaning when athletes reported being more alert they also reported being more calm; and a negative trend with bed time, meaning athletes who went to bed later at night reported feeling more tense. (See table 7)

Sub. sleep measures	**FCS**		**NP**		**PP**		**STAI-S**		**STAI-T**		**Mood**	
	N=19	p	N=20	p	N=20	p	N=20	p	N=20	p	N=20	p
Sleep Quality	-.097	.692	-.179	.450	.088	.713	**.582**	**.007**	.015	.949	**.698**	**.001**
Alertness	-.001	.997	-.148	.533	-.314	.177	.127	.594	-.134	.572	*.430*	*.059*
Fatigue	-.097	.694	.244	.299	**.533**	**.016**	-.105	.658	.002	.994	-.198	.403
Total Sleep Time	**-.575**	**.010**	.345	.137	*.399*	*.081*	.076	.749	-.199	.400	-.013	.956
Total Bed Time	**-.509**	**.026**	.348	.132	**.533**	**.016**	.029	.905	-.201	.395	.004	.987
Sleep Onset Latency	-.106	.667	.148	.534	.171	.472	-.241	.305	-.352	.128	.105	.660
Wake After Sleep Onset	.027	.912	.148	.549	-.017	.942	.067	.780	.238	.128	-.033	.889
Sleep Efficiency	.047	.850	-.122	.608	-.032	.895	.167	.482	.150	.527	-.066	.783
Bed time	.140	.568	.146	.539	-.169	.478	.067	.780	.125	.599	**-.491**	**.028**
Wake time	-.312	.194	*.387*	*.092*	.163	.493	.034	.887	-.036	.881	-.324	.140

Table 7. Injured phase subjective sleep measures correlated to injured phase function, night pain (NP), present pain (PP), STAI-S, STAI-T and mood. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend.

Injured phase actigraphy measures in relation to function, sleep, anxiety and mood

There was not any significant relationship found between actigraphy measures and function, pain, STAI-S, STAI-T and mood. (See table 8)

Actigraphy measures	**FCS**		**NP**		**PP**		**STAI-S**		**STAI-T**		**Mood**	
	N=17	p	N=18	p	N=18	p	N=18	p	N=18	p	N=18	p
Total Sleep Time	-.168	.518	.067	.791	-.001	.997	.257	.304	.317	.201	-.383	.117
Total Bed Time	-.353	.165	.280	.260	.321	.194	.257	.304	.149	.556	.106	.677
Sleep Onset Latency	.406	.106	.057	.822	-.075	.768	-.154	.541	.46	.160	-.040	.876
Wake After Sleep Onset	-.124	.634	.066	.794	.180	.475	.211	.401	-.021	.934	.359	.144
Sleep Efficiency	-.071	.787	.082	.746	-.021	.934	-.148	.559	.022	.930	-.286	.250

Table 8. Injured phase actigraphy measures correlated to injured phase function, night pain (NP), present pain (PP), STAI-S, STAI-T and mood. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend.

The relationship among: function, sleep, anxiety and mood at the injured phase

There was a significant positive relationship identified between BDI-II and STAI-T (p= <.001). When athletes scored higher level of depression, they also scored higher level of anxiety. Similarly to the relationship above, STAI-S had only a positive trend with BDI-II (p=.070). Moreover, a positive trend was found between ESS and STAI-T (p=.056), meaning athletes who scored high on the ESS, also scored high on the STAI-T. Also, there was a significant positive relationship between BDI-II and function (p=.044) which seem controversial since this result meant athletes who scored high on the BDI-II, meaning feeling more depressed, also scored high on the functional scale, meaning having less disability. There was another significant positive relationship that was found between PSQI and mood and also seem controversial (p=.010). This result meant athletes scoring high on the PSQI, meaning they were considered poor sleeper also reported feeling more calm.

Questionnaires	FCS		NP		PP		STAI-S		STAI-T		Mood	
	N=19	p	N=20	p	N=20	p	N=20	p	N=20	p	N=20	p
ESS	.065	.792	-.343	.138	-.144	.544	.076	.750	*.433*	*.056*	.129	.587
BDI-II	**.466**	**.044**	-.159	.503	-.316	.174	*.413*	*.070*	**.708**	**<.001**	-.240	.307
	N=18		N=19		N=19		N=19		N=19		N=19	
PSQI	.029	.909	-.200	.411	-.048	.844	-.342	.165	-.083	.744	**.576**	**.010**
PSQI-SE	.210	.403	-.055	.824	.204	.401	.290	.243	-.065	.799	-.036	.883

Table 9. Injured phase questionnaires correlated to injured phase function, night pain (NP), present pain (PP), STAI-S, STAI-T and mood. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend.

Correlation between sleep measures at injured phase to change in function and pain by the healed phase

We did not find any significant correlation which meant that none of the sleep variables were related to the change on function, pain, STAI-S and mood. However, there were a few trends; three with night pain and one with mood. We found that change in night pain had a positive relationship with subjective WASO (p=0.098), meaning as the change in night pain increased, reported subjective WASO tended to be longer during the injured phase. Similar results were found with bed time (p=.094) and wake time (p=.090). If there was a bigger change in night pain, athletes were likely to report later bed time and wake time during the injured phase. Concerning mood change, there was also a positive relationship but was with actigraphy SOL (p=0.078). Again, the bigger the change in mood appeared to be associated with a longer actigraphy SOL during the injured phase.

Sub. Sleep measures	FCS_Δ		NP_ Δ		PP_ Δ		STAI-S_ Δ		Mood_ Δ	
	N= 10	p	N=11	p	N=11	p	N= 11	p	N= 11	p
Sleep Quality	-.445	.198	-.258	.443	.298	.374	.515	.105	.318	.341
Alertness	-.065	.859	.233	.490	.000	.999	-.092	.787	-.060	.860
Fatigue	-.015	.966	-.216	.523	.199	.558	-.018	.959	.046	.894
Total Sleep Time	-.261	.466	.039	.910	.277	.409	.362	.274	.060	.860
Total Bed Time	-.153	.673	.122	.721	.286	.394	.166	.625	.131	.701
Sleep Onset Latency	.270	.451	.117	.732	.047	.890	-.343	.302	.304	.364
Wake After Sleep Onset	-.053	.885	.523	*.098*	.460	.154	-.119	.726	.142	.677
Sleep Efficiency	-.255	.477	-.222	.512	-.116	.735	.394	.231	-.244	.469
Bed time	.216	.549	.529	*.094*	.029	.932	.054	.875	-.142	.678
Wake time	.058	.874	.534	*.090*	.213	.529	.156	.648	-.035	.918
Actigraphy measures										
Total Sleep Time	-.124	.696	.013	.969	.159	.640	.118	.730	-.080	.814
Total Bed Time	-.176	.627	.109	.749	.300	.370	.174	.609	.131	.701
Sleep Onset Latency	.542	.106	.208	.539	.000	.999	.040	.906	.552	*.078*
Wake After Sleep Onset	-.187	.604	.245	.468	.449	.166	.213	.529	.470	.145
Sleep Efficiency	.184	.612	-.243	.471	-.454	.161	-.218	.521	-.513	.107

Table 10. Injured phase subjective and actigraphy sleep measures in relation to change in function, pain, STAI-S and mood. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend.

<u>Correlation between anxiety, depression, and sleepiness during the injured phase and change in function and pain by the healed phase</u>

We also wondered if any of the questionnaires was predicting any change in function and pain. We found to significant relationship which were between ESS and change in function (p=0.020) as well as between STAI-T and change in present pain (p=0.016). (See figures 3-4) This meant that the bigger the change in function was significantly related to more daytime sleepiness during the injured phase and also the greater the change in present pain was significantly related to more trait anxiety during the injured phase. In addition, two trends were also found where the larger the change in night pain appeared to be related to less daytime sleepiness during the injured phase (p=0.067) and the larger the change in mood was likely to be related to an higher score on the PSQI, which meant reporting poor sleep quality, during the injured phase (p=0.053).

Questionnaires	FCS_Δ		NP_ Δ		PP_ Δ		STAI-S_ Δ		Mood_ Δ	
	N= 10	p	N=11	p	N=11	p	N= 11	p	N= 11	p
ESS	-.714	**.020**	-.571	*.067*	-.047	.890	-.140	.680	.510	.109
BDI-II	.254	.479	.133	.696	-.070	.838	.433	.183	.443	.172
STAI-T	-.431	.213	.207	.542	.701	**.016**	.337	.310	.032	.924
PSQI	-.143	.693	-.208	.540	.142	.676	-.375	.256	.597	*.053*
PSQI_SE	-.105	.774	-.278	.408	.016	.962	.273	.417	-.009	.979

Table 11. Injured phase ESS, BDI-II, STAI-T, PSQI and PSQI-SE in relation to change in function, pain, STAI-S and mood. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend.

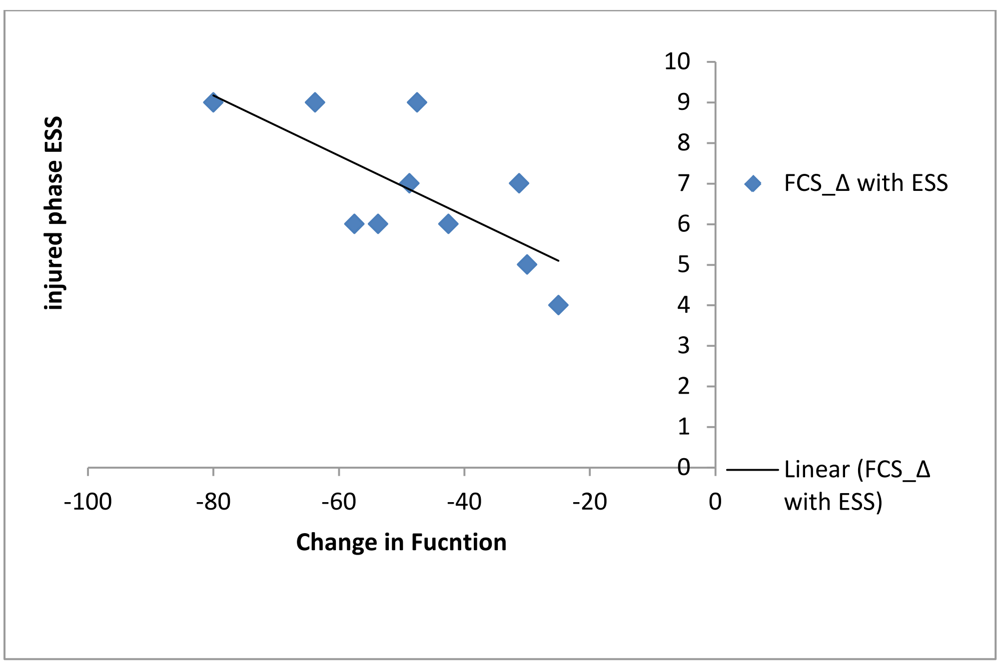

Figure 3. ESS in relation to change in function; r= -.714 and p= .020

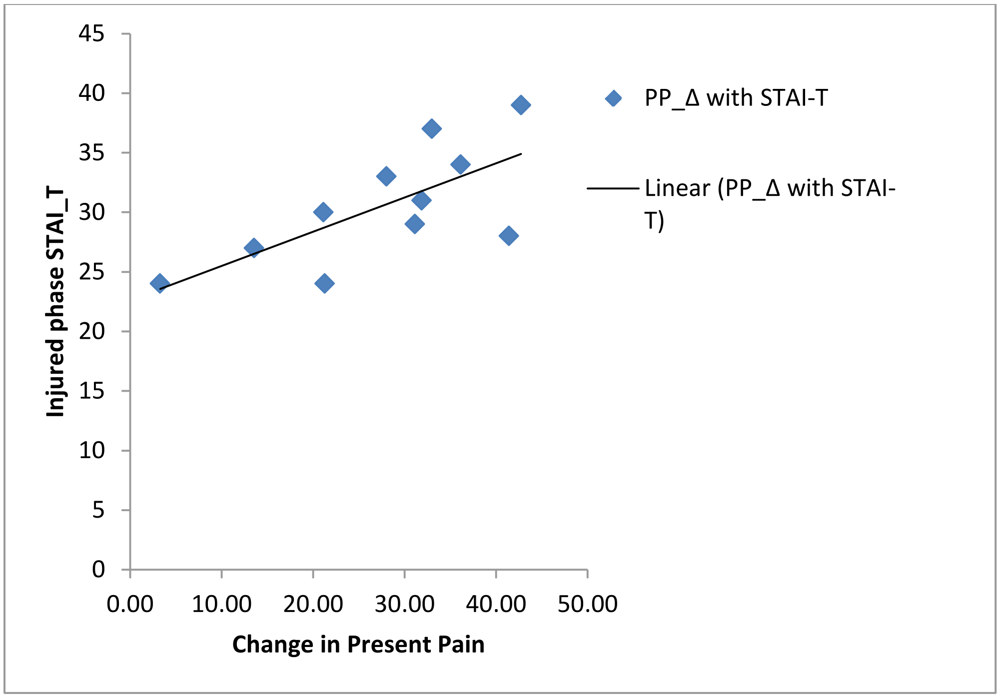

Figure 4. STAI-T in relation to change in present pain; r= .701 and p= .016

	Injured phase	Healed phase	N	p	Cov1 Sub.SE_IP	Cov2 Acti._SE_IP	Cov3 PSQI_IP	Cov4 ESS_IP
					p	p	p	p
Function	40.5 ± 20.2	88.5 ± 13.2	10	**<0.001**	.477	.612	.693	**.020**
Night pain (mm)	26.8 ± 16.6	4.4 ± 6.8	11	**0.002**	.512	.471	.540	*.067*
Present pain (mm)	31.8 ± 14.1	4.2 ± 6.6	11	**<0.001**	.735	.161	.676	.890
STAI_S	36.7±11.7	27.56±5.2	11	**0.023**	.463	.880	.114	.319

Table 12. The relationship between change in function, pain, and anxiety on subjective and objective sleep. Note significant covariate of ESS score for the change in function.

Correlation between function, pain during the injured phase and change in sleep measures, PSQI and ESS by the healed phase

We finalized our analysis by looking if function and pain could predict change in some sleep measures and ESS and PSQI. Only one relationship was found significant and this association was between injured phase night pain and change in ESS (p=0.031). (See graph 3) This relationship meant that the smaller the change in ESS was associated with a bigger night pain during the injured phase

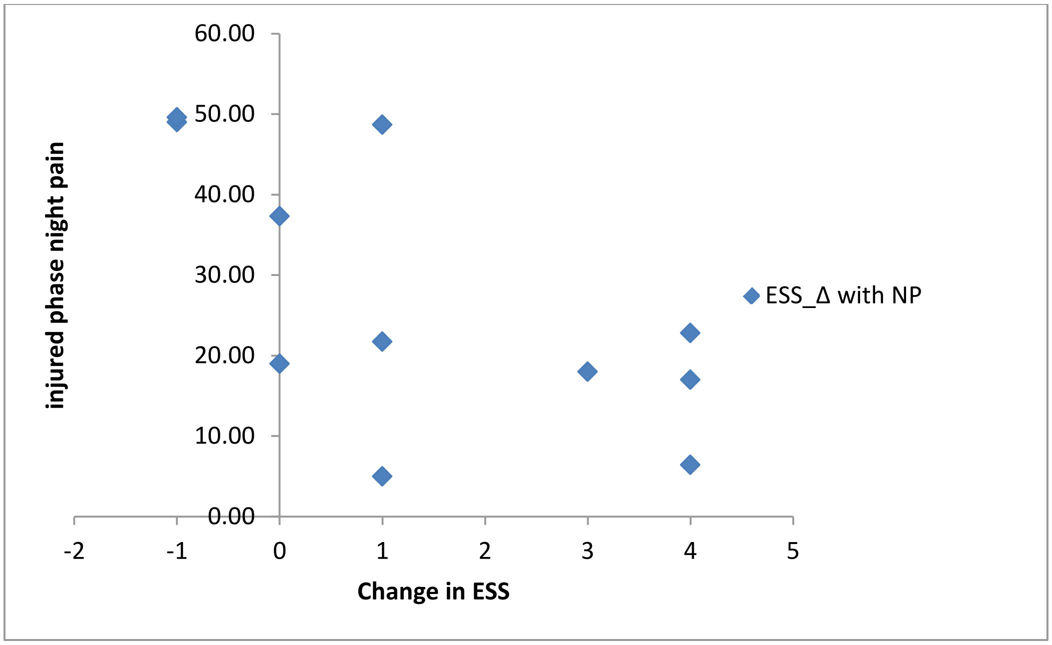

Figure 5. Night pain in relation to change in ESS; r= -.650 and p= .031

	SQ_Δ		Fatigue_Δ		Acti.SE_Δ		ESS_Δ		PSQI_Δ		N
Injured phase		p		p		p		p		p	
Function	.080	.826	-.178	.624	-.279	.435	-.348	.324	-.299	.401	10
Night pain	.345	.299	-.222	.512	-.133	.697	**-.650**	**.031**	-.501	.117	11
Present pain	.131	.701	.240	.477	-.157	.645	.050	.884	.095	.780	11

Table 13. Injured phase function, night pain, present pain in relation to change in subjective sleep quality, subjective level of fatigue, actigraphy sleep efficiency, ESS and PSQI. Numbers in **bold** meant the relationship was significant and numbers in *italic* meant the relationship had a trend

	Injured phase	Healed phase	N	p	N	Cov1 FCS_IP	N	Cov2 NP_IP	N	Cov3 PP_IP
						p		p		p
ESS	7.6±3.2	6.2±2.5	11	**0.034**	10	.324	11	**.031**	11	.844
PSQI	5.3±1.6	4.0±1.3	11	**0.008**	10	.401	11	.117	11	.780
Sub. SQ	63.8±10.2	73.6±12.7	11	**0.014**	10	.826	11	.299	11	.701
Fatigue	48.9±12.3	41.9±15.2	11	*0.065*	10	.624	11	.512	11	.477
Acti. SE	83.9±3.0	81.9±3.3	11	**0.042**	10	.435	11	.697	11	.645

Table 14 . The relationship between change in subjective and objective sleep on function, pain, and anxiety. Note significant covariate of night pain during the injured phase score for the change in ESS.

Awakenings reported in the journal during the injured phase and healed phase

Lastly, one of the variables we did not plan on originally studying were the number of wakes the subjects self reported during the night. We were interested to see if there was a difference between the injured and healed phase that may explain the difference in self reported sleep. Therefore we recorded the number of awakening after sleep onset during both phases to see if there were any obvious differences. During both phases, the majority of our athletes did wake up at least once to use the bathroom. The other main source of awakening was by noises or bed partner. Only a few of them were awakened due to discomfort or physical complaint.

Therefore, we assumed that their improvement in subjective sleep quality did not come from an improvement in subjective WASO.

Number of awakening	Day 1		Day 2		Day 3		Day 4		Day 5		Day6		Day 7	
	IP	HP	IP	HP	IP	HP	IP	HP	IP	HP	IP	HP	IP	HP
Subject 1	1	3	3	1	1	1	1	0	0	3	-	0	-	-
Subject 2	2	1	1	0	0	1	1	0	2	2	0	1	-	-
Subject 3	3	1	2	0	1	0	5	1	0	1	1	1	4	-
Subject 4	0	0	0	0	0	0	0	0	0	0	0	0	0	-
Subject 5	1	2	1	0	1	0	0	1	0	0	3	1	0	0
Subject 6	1	2	3	4	4	2	4	0	3	5	4	3	3	-
Subject 7	0	0	2	0	2	0	3	0	5	0	3	1	5	1
Subject 8	1	0	0	0	2	0	1	2	1	1	0	1	0	0
Subject 9	3	1	2	0	2	0	2	1	1	0	0	0	1	0
Subject 10	6	1	2	0	0	0	3	2	1	0	1	1	3	1
Subject 11	1	0	1	0	0	2	1	0	0	0	1	0	2	1

Table 15. Number of awakening following sleep onset during the injured phase (IP) and healed phase (HP).