Sleep Deprivation in Relation to Pain

How Does Sleep Deprivation Affect Pain Perception and Endurance?

Psychology

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Introduction

Sleep disorders are very common among the American population, as over 50 million Americans have sleep-related problems (The State of Sleep Health, 2017). The importance of sleep is known by many, as it is the body's recovery period and allows proper function during its wake-period. Because this is such a prevalent issue in society, there is abundant research on what causes sleep disorders and how to minimize them, however, this study will look into the effects of sleep deprivation relating to pain. The question this investigation will be researching is **how does sleep deprivation affect pain perception and endurance?** Because of the widespread causes of sleep deprivation, whether it be anywhere from a tight schedule to a diagnosed sleep disorder, it is difficult to solve the problem entirely. Because of this, it is important to study the effects it has on the individual, and from here, build on this foundation to create solutions. It is human nature to try to minimize pain, so it is interesting to research how two very prominent issues people deal with, sleep deprivation and pain, affect each other. Sleep deprivation causes an increase in pain sensitivity and a decrease in pain threshold and regulation.

Sleep deprivation is simply a lack of sleep and can be caused by sleep disorders such as insomnia or causes that aren't due to an underlying disease, such as an excessive caffeine intake. In the studies analyzed in this investigation, sleep deprivation is caused by having the subject(s) stay up for a certain duration of time, the duration being specified in each analyzation of the studies. For the second part of the research question, pain perception and endurance are measured by different means following the sleep deprivation or ad hominem. The studies included may test other aspects of pain, but only the previously stated aspects of pain will be discussed in regards to the research question. Pain perception refers to sensitivity and regulation

and pain endurance refers to threshold. Pain perception and endurance cannot be completely separated into two different categories, as one affects the other. The way pain is perceived affects the threshold. For example, the intensity of pain perceived affects the tolerance of the pain, the endurance of it. Although they can be separately tested, it is important to understand their effects on each other. The type and how the pain are measured is also specified in each study analysis.

Research

Studies on Pain Perception

Focusing specifically on sleep deprivation's effect on pain perception, the study, "The Effect of Sleep Deprivation on Pain Perception in Healthy Subjects: A Meta-Analysis" done by M. Schrimpf et al. will be analyzed (M. Schrimpf et al., 2015). The aim of this meta-analysis derived from the existing strong-evidence indicating an interaction between sleep and pain but sought clarity on the size of this effect as well as the clinical relevance (M. Schrimpf et al., 2015). Thus, this meta-analysis was conducted to quantify the effect of sleep deprivation on pain perception. The studies chosen for this meta-analysis were narrowed down from a large pool of studies on this subject by factors such as age and health of the subjects and consistency of their procedure, referring to a similar, if not the same, independent and dependent variable. As a result of their searching procedure, 34 eligible studies were identified, 5 of which were included in this meta-analysis, the rest excluded for various systematic reasons that didn't fit the requirements of this meta-analysis. In the 5 studies, Azevedo E, Manzano GM, Silva A et al. (2011)(1), Haack M. Lee, Cohen DA, et al. (2006)(2), Haack M, Mullington JM (2005)(3), Ablin JN, Clauw DJ, Lyden AK, et al. (2013)(4), and Kundermann B, Spernal J. Huber MT, et al. (2004)(5), had a total of 190 participants. The participants were completely sleep deprived in three of the studies,

1, 2, and 5, and sleep restricted (4-6 hours of sleep per day) in the other two, 3 and 4. All five studies used one or more visual analog scales to measure pain, and two studies additionally analyzed pain threshold using quantitative sensory testing. This meta-analysis confirms the effect of sleep deprivation on pain perception. A medium effect (SMD = .62) was found for the between-group analysis and a large effect (SMD = 1.49) was found for the within group analysis. The standardized mean difference conducted by the researchers of this meta-analysis confirms the effect of sleep deprivation on pain perception, as sleep deprivation increased self-reported pain and affects evoked pain responses obtained through somatosensory testing protocols (M. Schrimpf et al., 2015). The type of pain tested may limit the applicability of the results, for they cannot be directly applied to patients with chronic pain disorders since it was tested on healthy subjects. However, this simple measurement of pain compared to baseline measurements still supports that sleep deprivation does have an effect on pain. This meta-analysis is important on establishing connections between sleep deprivation on healthy subjects and eventually can be compared to patients with chronic pain disorders when they are used in the study. A strength of analyzing this information by meta-analysis is how the researchers were able to compare the studies side by side, allowing for clear identification of both the strengths and limitations of the studies used based on their design, samples, and ultimately their results. This meta-analysis can be used as a control group, in a way, for future studies regarding this topic because they had strict requirements of what the studies had to be testing to be included, keeping their aim consistent of directly assessing the effect of sleep deprivation on pain perception and endurance. So, although these results cannot yet be used for all pain conditions, it supports the argument of sleep deprivation causing an increase in pain sensitivity and a decrease in pain endurance when regarding healthy subjects.

Studies on Pain Endurance

Focusing specifically on the effects of sleep deprivation on pain endurance, the study "Sleep deprivation and recovery Sleep Prior to a Noxious Inflammatory Insult Influence Characteristics and Duration of Pain" done by Giancarlo Vanini, MD, looks into this (G. Vanini, 2016). This study states how insufficient sleep and chronic pain are public health epidemics, as sleep loss worsens pain and predicts the development of chronic pain. The objective of this study is to test whether acute sleep deprivation and recovery sleep prior to formalin injection alter post-injection pain levels and duration. Essentially it is determining a link between whether previous, acute sleep loss and recovery sleep determine pain levels and duration, for there has not been a clear connection tested before. In doing so, they used 48, n=48, male Sprague-Dawley rats that underwent sleep deprivation or ad libitum, the proper amount of sleep, for 9 hours. The rats were then assigned the injection they would receive, either the control or experimental injection. This is a strength in the design of the experiment, as the researchers were able to control from soreness post-injection in general by having a placebo injection. The results of these condition after 21 days were compared to their baseline measurements. The results showed that the rats that received the experimental injection had bilateral mechanical hypersensitivity (allodynia) that persisted for up to 21 days post-injection. The rats that were assigned to the sleep deprivation group significantly enhanced bilateral allodynia, pain perception. There was a synergistic interaction when sleep deprivation preceded the experimental injection. By using the experimental injection in rats assigned to both a recovery period and no recovery period, the researcher was able to show a clear connection between the amount of sleep deprivation and recovery on pain perception and pain endurance specifically (G. Vanini, 2016). Sleep depriving

the rats assigned to that treatment group, the rats that received the experimental injection, raises some ethical concerns. However, these concerns are limited because the way in which they were sleep deprived does not cause them lasting physical or emotional harm, as total sleep deprivation was accomplished by mild auditory and tactile stimulation. Another ethical concern is the way in which pain is inflicted and the severity of it. The formalin injection, which elevates pain levels, specifically, raises ethical concerns because the researchers were deliberately causing the rats pain. Similar to the ethical precautions of sleep depriving the rats, the researchers ensured no tissue damage by having a cut-off time for the thermal stimulus of 15 seconds. Regarding gender, only male rats were used in this study. Since this experiment used rats and not humans, the gender will not have a dramatic impact on the results. However, the lack of female rat participation may have an unknown effect as well as decrease the applicability. The results from this experiment support the conclusion that sleep loss preceding an inflammatory insult worsens the subsequent pain levels and can increase susceptibility for that pain to persist (G. Vanini, 2016). This study tests an additional variable of pain prior to sleep deprivation in addition to how sleep deprivation affects pain perception and endurance. The implications of the results of this study leads to discussion about how not only does pain cause an increase in pain sensitivity, perception, but also increases the duration, endurance, of pain that was inflicted prior to the sleep deprivation. This leads to further discussion of how different variables come into play when studying sleep deprivation's effect on pain, being the pain prior inflicted in this study. As previously mentioned, the use of rats instead of humans greatly limits the applicability of these results, however, it creates a foundation for studies resembling this one in the future.

Studies on Pain Perception and Pain Endurance

Although pain perception and pain endurance are separate effects of sleep deprivation, their properties intersect. The study V. Busch and J. Haas et al. (2012), "Sleep Deprivation in Chronic Somatoform Pain- Effects on Mood and Pain Regulation," aims to investigate the effects of total sleep deprivation on pain perception and mood in patients with chronic somatoform pain (V. Busch and J. Haas et al., 2012). When compared to the study "Sleep Deprivation Affects Thermal Pain Thresholds but not Somatosensory Thresholds in Healthy Volunteers" (B. Kundermann et al., 2004), the results allow the difference in method and conclusions to be compared and analyzed. For the study conducted by V. Busch et al, twenty patients with a somatoform pain disorder according to ICD-10 diagnostic criteria were sleep-deprived for one night, followed by one recovery night. Clinical pain complaints (visual analog scale), detection and pain thresholds (temperature and pressure) as well as mood states (profile of mood states) were assessed on the day prior to the experiment, of deprivation and after recovery sleep. The results showed a significant increase of the self-reported pain on the visual-analog scale (VAS) the day after sleep deprivation. Thermal and pressure pain thresholds did not change following the night of sleep deprivation, but even increased after the recovery night. These results indicate that there may not be a direct relationship between pain perception and endurance after sleep deprivation, as the participants' self-rated pain perception increased after sleep deprivation whereas their pain endurance increased; sleep deprivation had an opposite effect on them. This leads to discussion about if sleep deprivation has a greater effect on pain perception, mental, than endurance, physical (V. Busch et al., 2012). For the method of the study conducted by B Kundermann et al. (2004), twenty healthy volunteers were randomly assigned either to two nights of total sleep deprivation or two nights of undisturbed night sleep. Sleep deprivation

nights were separated by two days with normal night sleep. Baseline measures were taken for heat and cold pain thresholds as well as measurements after the night of either sleep deprivation of undisturbed sleep. These results indicated that sleep deprivation significantly decreased heat pain thresholds after both nights of sleep deprivation. No significant changes were detected in thresholds for the control group. These results suggest a positive correlation between sleep deprivation and a decrease in pain threshold. Although both studies tested for sleep deprivation's effect on pain perception and endurance, their results differed greatly. The differences in results between these two studies may be due to the method themselves. The study V Busch et al (2012) did not use healthy subjects, as they were patients with somatoform pain disorder. This type of participants may have underlying effects on the results obtained, so it is difficult to directly compare the results of the two studies, as B Kundermann et al. (2004) used all healthy participants. For this reason, the results of B Kundermann et al. (2004) are more relevant when investigating how sleep deprivation affects pain perception and endurance, as it is crucial to see the effects on healthy subjects to use as a future control when investigating unhealthy subjects. However, the results of V. Busch et al. (2012) are still valuable to see how sleep deprivation affects different groups of people, thus increasing the applicability of sleep deprivation's effect on pain.

Human and Animal Studies Compared

There is substantial value in comparing human studies to animal studies in both their design and results to see if the results from animal studies are able to further support human studies when testing for and manipulating similar variables. The meta-analysis "The Effect of Sleep Deprivation on Pain" done by B. Kundermann, J-C Kreig, W. Schreiber, and S. Lautenbacher includes both human and animal studies on this subject (B. Kundermann et al.,

2004). The design of human and animal studies differed due to ethical concerns, as human studies inflicted only short-term sleep deprivation (up to three nights), providing only limited generalization to chronic pain conditions, for example, which have a much greater period of sleep deprivation. The amount of time in which sleep deprivation is inflicted in a study can be greater in animal studies, allowing for the results to be applicable to more conditions of pain caused by sleep-deprivation, slowly creeping towards studies that are applicable to individuals with chronic pain, as previously mentioned. The studies this meta-analysis included sleep deprived their subjects from one to four days. Individual factors are more difficult to control in human studies, as the person's normal eating and sleeping conditions, stress levels and other factors can be confounding variables on the results. Individual factors, such as age or sex of the study subjects, as well as the aforementioned factors, have yet to be controlled sufficiently and may interact with the effects of sleep deprivation on pain in human studies. These factors are able to be controlled better in animal studies, as the researcher can keep a 24/7 watch on the rats for as long as they need to see through until the end. Due to the inability to control the aforementioned variables, the findings of human studies are not always consistent. However, even with these inconsistencies, the studies do overall tend to indicate that sleep deprivation does produce hyperalgesia, an increase in pain sensitivity, changes in healthy subjects. The disruption of slow wave sleep, deep sleep, especially appeared to produce hyperalgesic change, describing the direction of change in pain sensitivity. Findings by Onen et al. (2001) suggest that slow wave sleep deprivation makes individuals more sensitive to noxious stimuli. The hyperalgesic changes of this type of sleep deprivation was mainly observed when tested by pressure pain stimulation (Onen et al., 2001). These findings of pain in pressure points along with the findings of Lentz et al. (1999) "corroborate the idea of systematic change in pain sensitivity because similar results

were obtained while testing multiple sites" (Lentz et al., 1999). The data from animal studies is much more consistent than those obtained from human studies because of the ability to control more variables. REM sleep deprivation was observed to increase nociceptive behavior in almost all studies. This suggests a hyperalgesic action of REM sleep deprivation. The exclusive focus on REM sleep deprivation in certain studies does leaves room for question whether the observed effects are not specific to REM sleep deprivation but rather a general and unspecific disruption of sleep. Although human and animal studies go about investigating the effects of sleep deprivation on pain differently, their results are consistent in that whatever type of sleep deprivation occurs; there is an effect on pain perception and endurance. However, due to the specific type of sleep deprivation done in animal studies, REM sleep deprivation, it is not applicable to humans without further research because there are few human studies done with this type of sleep deprivation, so we are unable to compare the results to see if animal studies could be applicable to humans. However, their general nature can aid in predicting what will occur in human studies.

As can be concluded from the many strengths and limitations of both human and animal studies, it is crucial to regard both when drawing conclusions on a matter. Regarding both human and animal studies on sleep deprivation's effect on pain perception and endurance, the majority of studies in both realms suggest sleep deprivation both increases pain sensitivity and decreases pain tolerance.

Conclusion

With everything, there are both strengths and limitations of studying this particular subject. A limitation of comparing studies on the correlation between sleep deprivation are the ways in which sleep deprivation is created and the duration of it. For example, in the first meta-

analysis analyzed, “The effect of sleep deprivation on pain” (B Kundermann et al., 2004), it looks at Moldofsky and Scarisbrick (1976) and Drewes et al. (1997) who, when studying this subject, sleep deprived their experimental group for three consecutive nights and just one night, respectively (Moldofsky and Scarisbrick, 1976, Drewes et al., 1997). Moldofsky and Scarisbrick (1976) results showed a decrease in pain threshold whereas Drewes et al. (1997) results indicated there being no change in pain threshold. These two studies highlight the limitation of studying this subject, and may explain why human studies’ findings are often inconsistent; the methods in which the researches to conduct the experiment can have an impact on the results. However, in the same meta-analysis, there is a trend that studies that sleep deprive their subjects for 3 consecutive nights have a decrease in pain threshold, such as Moldofshy et al. (1975) and Lentz et al. (1999). This further illustrates how although studies may be testing pain based off of the same independent variable, amount of sleep, the amount allowed for the subjects can drastically change the results, thus there should be an emphasis on noting the amount when comparing studies. Another limitation is the subjectivity of the dependent variable, measuring pain, because everyone has a different pain tolerance. When studies measure pain by self-reported scales, for example, the data is immediately limited by this subjectivity. The concept of effect on pain levels automatically raises ethical concerns, as the researchers want to ensure the participants do not have permanent mental or physical harm done to them, and same goes for sleep deprivation not having long-term negative consequences. There is great importance in ensuring the safety of the participants, however this in turn limits the results, as researching long-term effects of sleep deprivation on pain would be difficult while remaining within ethical boundaries.

A strength on studying this subject is the applicability of measuring pain. The studies showed a great variety of how this is done, allowing for this topic to be applied to many aspects

of pain. In the studies previously analyzed in this investigation, as well as some studies within the meta-analysis but not specifically mentioned, some of the pain-related measurements include: pressure pain sensitivity, muscular pain, and pain thresholds-mechanical and thermal. This demonstrates the applicability of studying sleep deprivation on pain because researchers are able to test multiple types of pain in one study. Throughout the analyzation of these studies, gender was not a major component, if even specifically mentioned at all. In order to ensure the largest applicability of the results, it would be valuable to separate gender and see if it has an effect on the results.

Due to the prevalence of sleep-related disorders in today's society, it is crucial to look into what effects this has on the individual as well as the possible implications it may have. As shown by this investigation, sleep deprivation causes more than just sleepiness and may have other affects in addition to a change in pain perception and endurance that have yet to be investigated. As displayed by the majority of the results of the studies included in this investigation, sleep deprivation does, in fact, cause an increase in pain sensitivity as well as a decrease in pain threshold. The extent to which these results appear in their respective study seems to change based on the method of said study, such as the health of the participants, thus, creating some confusion when looking for a definite answer to the question, "how does sleep deprivation affect pain perception and endurance?" Despite this limitation when comparing studies, the design of these studies does allow for multiple pain types to be tested, leading way for deeper research on this matter.

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